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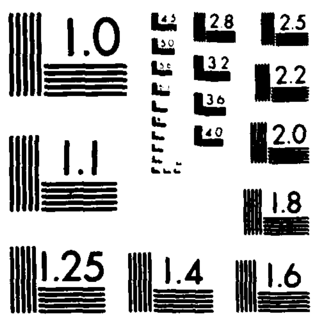

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Operational and Functional Description of the AERA Packages

September 1983
Report No. DOT/FAA/ES-83/10

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16. Abstract

AERA consists of a series of new or enhanced software functions which help the performance of en route air traffic control. Current planning calls for the AERA functions to be developed incrementally in a series of six separate packages.

This document presents an overview of the AERA packages, with particular emphasis on the way the AERA functions interact with other ATC functions and with the controller. Functional descriptions of each package present the logical organization of the AERA functions, including the role of each function and the interfaces between functions. The operational descriptions discuss how the AERA functions will be used by the controller: when the function is invoked, what information is exchanged between the function and the controller, and how the controller is expected to respond.

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EXECUTIVE SUMMARY

INTRODUCTION

The Federal Aviation Administration (FAA) is currently in the process of developing a new computer system, called the Advanced Automation System (AAS), to help control the nation's air traffic. The AAS will consist of new or enhanced hardware (i.e., Central Processing Units, memories, and terminals) and new software.

The new software will retain most or all of the functions in the existing NAS (National Airspace System) En Route Stage A software, but recoded and possibly using different algorithms. In addition, the new AAS software will contain several new functions that make greater use of the capabilities of automation for Air Traffic Control (ATC). These new functions will represent the initial implementation of the concept known as AERA.

When fully implemented, the AERA functions are intended to detect and resolve many routine ATC problems automatically, and act to implement those resolutions. The controller will not need to be fully involved with such routine situations, and will thus have a greater capability for maintaining an overall control plan and dealing with less routine problems. The result is planned to be a significantly enhanced control capability, with benefits for airspace users and increased levels of controller productivity and safety.

The AERA functions will be introduced as a series of packages to provide a staged evolution of capability. AERA will initially appear to the controller as a set of problem detection and planning tools to help move traffic more effectively, but it will develop into an automated resolution and decision-making system. Such full automation of the air traffic control process is the final stage to be described in this paper, although it may never be completely achieved.

PURPOSE AND SCOPE

There are three principal goals for providing additional automation assistance to the air traffic controller:

- increasing services to the users
- increasing controller productivity
- improving system safety

These benefits are to be obtained through the implementation of the AERA concept. The highest level of benefits would come from the

highest degree of automation, but the FAA recognizes that a completely automated ATC system cannot be implemented immediately. Aside from the technical challenges, there are possible problems of safety, controller training, and controller acceptance if the ATC system is automated too quickly.

Consequently, implementation of the AERA functions is planned to occur in a series of stages. Each stage of development, or "package," would provide for additional automation capability in several functional areas, in a manner which enhances the capabilities of the system as a whole and forms the basis for the next incremental package. This series of AERA packages was described in MITRE report WP-83W149, "Evolution of Advanced ATC Automation Functions," which presented the rationale for the particular functions and enhancements in each package.

The work described in this report provides additional detail for the package descriptions. The packages, as defined in WP-83W149, were investigated with special attention to:

- How the new functions and enhancements interface with each other and with other functions of the ATC system.

- How the controller will be affected by the new functions, and how they can be used to control traffic.

The functional and operational descriptions, respectively, will discuss the results in these areas.

These descriptions are not intended to be a blueprint for the implementation of these functions. This material is, rather, a recommendation for a line of development to follow. The investigations were intended to disclose areas for additional research and to provide a framework for decision-making. Changes to these descriptions are not only expected, they are the desired result of documenting current thinking.

DESCRIPTION OF THE AERA PACKAGES

A simplified overview of the development of the AERA packages is shown in Figure A. In this diagram, each vertical column represents a separate stage of automation; enhancements to the functional areas are arranged horizontally from left to right.

The initial package of advanced automation features, referred to as AERA 1.01, will be implemented as part of the initial Advanced

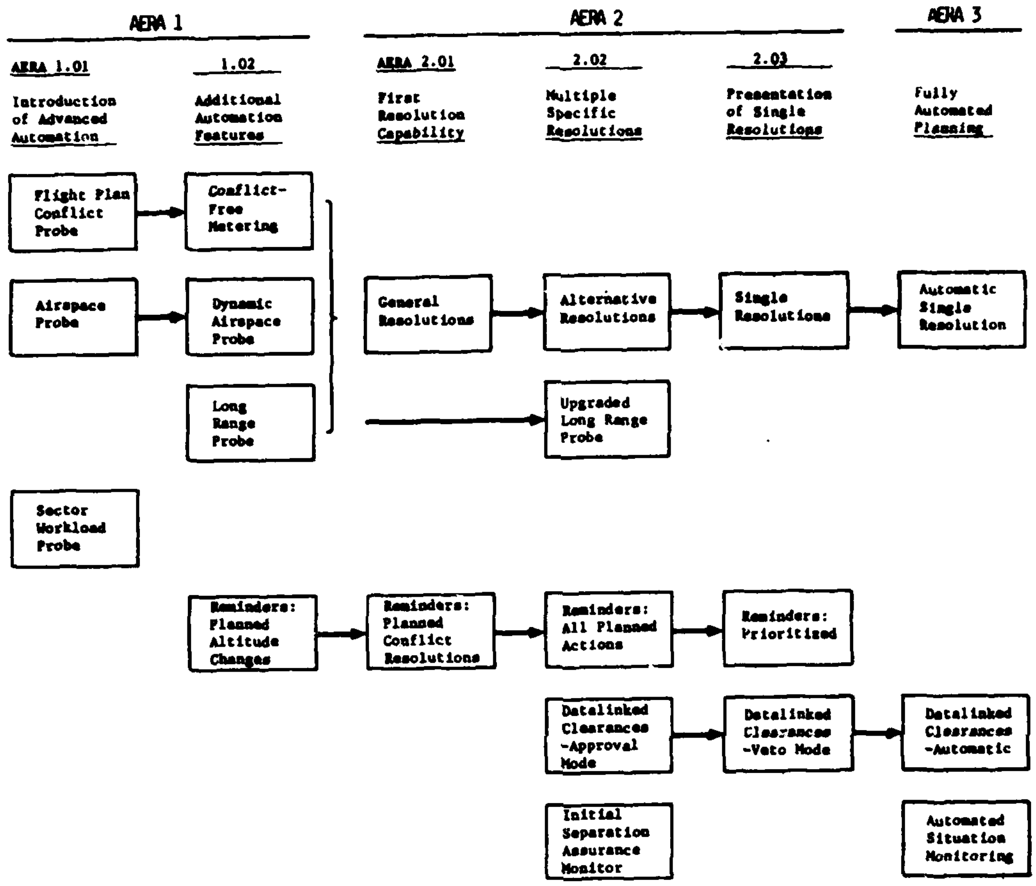

FIGURE A
OVERVIEW OF THE AERA PACKAGES

Automation System of hardware and software. AERA 1.01 will introduce automated planning tools which use the aircraft flight plan data. AERA 1.01 will consist of four functions:

- Trajectory Estimation will calculate the flight path of the aircraft in four dimensions, based on information from flight plans and other sources.
- Flight Plan Conflict Probe will compare aircraft trajectories in order to test for conflicts between aircraft.
- Airspace Probe will use the aircraft trajectory to test for conflicts with special use airspace and terrain.
- Sector Workload Probe will display various workload-related measures to supervisory personnel.

AERA 1.02 will add several new functions and will integrate the advanced planning functions more closely with the existing functions. A Long Range Probe capability will be added to help the controller evaluate off-airway route requests which extend beyond the prediction horizon of the Conflict Probe. The Airspace Probe will be enhanced to consider conflicts with dynamic weather areas, as well as with static areas of special use airspace. Metering advisories to the controller will be checked for potential conflicts before being displayed. The controller will be able to make more of the overall control plan known to the automation system, which in turn will provide reminders of planned actions at the appropriate times.

In AERA 2, these functions will be enhanced to improve controller productivity. Three steps are planned for AERA 2. The first, AERA 2.01, will introduce a computer capability for helping the controller to resolve those problems detected by the other advanced automation functions. Initially, this capability will consist of general advisories presented to the controller, with the controller adding the necessary details. In AERA 2.02, the controller will be presented with several specific, complete resolutions; if one is selected, it will be automatically converted into a datalinked clearance to be sent to the aircraft upon approval. In AERA 2.03, only a single resolution is displayed to the controller. If the resolution is approved, it is translated into a clearance which is presented to the controller and automatically datalinked to the aircraft unless specifically vetoed by the controller. The resolutions and reminders are assigned priorities by the system, based upon a global planning perspective.

Finally, full automation is applied to the ATC system in AERA 3, allowing routine planning and resolution actions to be conducted without controller intervention. The controller is then left free to deal with special situations.

The above survey of the AERA packages has been provided in order to establish a sense of how the ATC system is seen to develop over time with the introduction of the automated functions, and how the individual packages contribute to the goal of full ATC automation. The remainder of this summary presents a functional and operational overview of each package.

<u>AERA 1.01</u>

The first package of AERA functions will include:

- Trajectory Estimation
- Flight Plan Conflict Probe
- Airspace Probe
- Sector Workload Probe

These functions will be installed in the AAS, in addition to the automated functions currently available in NAS Stage A and the other functions which will be implemented in the "host" computers prior to the AAS, such as En Route Metering II and IFR/VFR Conflict Alert.

Trajectory Estimation will construct a four-dimensional (x,y,z,t) description of the planned flight path of each controlled aircraft within the planning region of the Area Control Facility (ACF), using information from the filed flight plan, stored aircraft performance data, and available data on winds and temperatures aloft. When significant deviations from this trajectory are detected, it will be recomputed in a way which attempts to compensate for the errors in the input data ("resynchronization"). Trajectories will also be recomputed to reflect flight plan amendment messages entered by the controller. The trajectory should always represent the best available estimate of the future position of the aircraft. The controller's compliance in following good current control practices, in terms of entering flight plan amendment messages when new clearances are given and maintaining conformity between the aircraft and its cleared route, is critical to the accuracy of the trajectories and the accuracy of the other planning and control functions.

Flight Plan Conflict Probe (FPCP) compares aircraft trajectories to detect situations in which the required separation between aircraft may or will be violated. If immediate controller action is not required to resolve the conflict, it is termed an Advisory Conflict,

and the controller receives an advisory message from the probe. If prompt action by the controller is deemed necessary to avoid a separation violation, a Priority Conflict is declared and the controller receives a priority message. The advisory and priority messages contain sufficient information to identify the conflict for the controller; additional information may be available in the form of an optional graphic situation display. FPCP considers the entire valid length of the trajectory, which may extend across the entire ACF Planning Region. Predicted violations are not necessarily displayed immediately to the controller; the message is presented to the controller at a time which depends on such factors as the time of separation violation.

The Airspace Probe compares individual aircraft trajectories against the stored data base of special use airspace and terrain protection regions which the aircraft may not be allowed to penetrate. The controller will be notified as soon as an airspace violation is predicted. If more than a specified (system parameter) time exists before the violation, an advisory message will be received; the controller can then inform the pilot involved so that the pilot can replan the route or obtain authorization to enter the airspace. If less than a specified time, the controller will direct the aircraft to avoid the airspace region.

Both Flight Plan Conflict Probe and Airspace Probe will be invoked automatically whenever a new trajectory is added or an existing trajectory is modified or automatically updated. These functions may also be invoked by a controller request to test a proposed flight plan amendment for conflicts, as part of the Trial Plan Probe capability.

Sector Workload Probe uses the aircraft trajectories and the results generated by FPCP and the Airspace Probe to derive several workload-related measures. These measures are then used by the Area Supervisor or Area Manager to assist in various decisions on staffing and sectorization (combining and decombining sectors). The supervisor will be able to specify the measures to be displayed, the level of detail, the geographic and time region to be considered, and the trigger for displaying the information: on demand, periodically, or when a preset threshold is violated.

AERA 1.02

This package adds some new automation functions to those introduced in AERA 1.01 and integrates the automation functions more closely. The following functions are new to AERA 1.02:

- Long Range Probe
- Conflict-Free Metering
- Dynamic Airspace Probe
- Controller Reminders

In addition, capabilities will be added to transmit text messages entered by the controller to datalink-equipped aircraft, to utilize aircraft performance data automatically downlinked by datalink-equipped aircraft, and to detect deviations from the aircraft's cleared speed. The functions introduced in AERA 1.01 and previously will also be modified to improve system performance.

The Long Range Probe (LRP) is an aid to the controller for determining if possible control problems may exist beyond the range of the Flight Plan Conflict Probe. In AERA 1.02, LRP will be invoked automatically when an off-airway route is first requested, and possibly at other appropriate times.

LRP is expected to help the ATC system accept more off-airway User-Preferred Routes (UPRs), by providing the controller with information about areas of high traffic density which might affect the UPR, as well as facilitating the efficient application of ATC-preferred routes. The process for accomplishing this may involve the designation, by appropriate supervisory personnel, of "protected airspace" around busy traffic flows which would be avoided by the UPR. Automation aids also may be introduced to help establish and implement "preferred routes" to avoid the high-density areas. Enhanced versions of this function in later AERA packages are expected to be more dynamic, presenting information to the sector controller for evaluation or automatically determining if a UPR is acceptable, on a case-by-case basis. Much research will be required to determine the form and characteristics of the Long Range Probe for AERA 1.02 and beyond.

AERA 1.02 will also include an enhanced version of the Airspace Probe introduced in AERA 1.01. The enhancement will consist of the capability to detect encounters between an aircraft trajectory and a moving region of airspace, such as an area of hazardous weather. Information on the dynamic airspace region will be provided by a source external to AERA (e.g., Center Weather Service Unit or Central Weather Processor).

The output of the Dynamic Airspace Probe will be a message to the controller containing information about the predicted encounter. The controller will then inform the pilot and be prepared to assist the pilot to avoid the hazardous area. Controller responsibilities would be unchanged from the current ATC system, although more information on the weather area would be available.

Conflict-Free Metering will be provided in AERA 1.02 by integrating the metering function (introduced prior to the AAS) with the AERA conflict probe functions. Metering advisories will be checked by the probes for conflicts before the advisory is displayed to the controller and, if a conflict is detected, the advisory will be modified as appropriate.

The metering advisories presented to the controller will be conflict-free only within the limits of the probes; that is, the controller will still need to monitor for conflicts with VFR aircraft or with aircraft that are not in conformance with their trajectories. A conflict may also exist beyond the time horizon of the probe. Lastly, the metering advisory cannot be guaranteed to be conflict-free beyond the metering fix, since the goal of the metering advisory (delivering the aircraft to the metering fix at a specific time) will not be changed.

The Metering Planning function in AERA 1.02 may also allow the controller to request an alternative advisory if the one displayed is unacceptable. The controller may be able to request a specific type of maneuver, such as a metering vector, or may simply request the "next best" alternative.

The last major new feature of AERA 1.02 is the provision of Controller Reminder messages. These are similar in purpose to the metering advisory messages in that they inform the controller of a clearance which should be delivered to the aircraft. The aim of this capability is to help maintain the reliability of the aircraft trajectories, by first giving the controller a means for inserting planned control actions into the trajectory and by then providing reminders at the appropriate time to perform that control action.

The initial implementation of Controller Reminder messages is to be limited to altitude transitions only. These planned transitions may be derived from the flight plan according to routine procedures and Letters of Agreement, or they may be generated directly by the controller. The reminder messages may be inhibited in cases where they would not be helpful, such as for standard descents into a major airport. Upon receipt of a reminder message, the controller will normally deliver the planned clearance, but will also be free to change the clearance as appropriate.

In order to process the planned actions and reminder messages, and monitor aircraft conformance to the intended maneuver, AERA 1.02 introduces a functional component termed Tactical Execution. The Tactical Execution function is notified when the activation point for a planned action is reached; it then notifies the controller. If the controller implements the planned action, Tactical Execution

monitors the maneuver and alerts the controller to any significant deviations detected (such as an actual descent gradient which would put the aircraft outside the altitude band protected by Flight Plan Conflict Probe).

AERA 2.01

In addition to qualitative improvements to the previously introduced functions, AERA 2.01 includes the capability to present general resolutions to the controller for problems detected by the automated probe functions. The Metering Planning function is also enhanced to allow the controller to approve the entire metering plan for an aircraft, rather than only individual advisories as they occur.

The general resolution advisory provided in AERA 2.01 consist[illegible] of an aircraft ID and the general maneuvers which can be perf[illegible]ed to resolve a specified conflict. The specific parameter[illegible] of the maneuver will be filled in by the controller. The [illegible]letely specified maneuver may then be submitted to the Trial Plan [illegible]be, to verify that it does indeed resolve the conflict without cr[illegible]ing any new ones.

The resolution may be only partially specified; for example, a vector to parallel an airway at a specific offset might not include a start-of-maneuver point or a point to turn back to the airway. The Trajectory Estimation component will be enhanced to allow processing such planned actions where the goal is known, but not the details of the maneuver to achieve that goal. Reminder messages will be displayed to the controller by the Tactical Execution function at the appropriate time to implement the planned resolution.

The complete metering plan for an aircraft may also be displayed to the controller for approval. In En Route Metering II (ERM II), advisories are presented singly, but they are designed to absorb only a portion of the necessary delay, with later maneuvers expected to absorb the remainder. It is expected that by this stage of the automation development, the effect of a metering advisory will be predicted accurately enough that the later advisories can be planned at the same time.

Controller approval of the metering plan will allow the metering maneuvers to be incorporated into the aircraft's trajectory as the best estimate of the actual path of the aircraft. In AERA 2.01, incorporating the maneuvers before the clearance is delivered to the aircraft may present some operational problems, but it is expected in most cases to result in more accurate trajectories and better conflict predictions.

The controller will then be notified, at the appropriate time, of the next metering maneuver for the aircraft. Prior approval of the metering plan will not prevent the controller from modifying the plan later, as needed, nor will it mean that the advisories themselves would not be changed later (to avoid a newly developed conflict, for instance). Such changes would need to be reflected in the trajectory as soon as possible, however.

AERA 2.02

The Conflict Resolution Planning function introduced in AERA 2.01 is enhanced in the next stage to provide the controller with a set of several specific resolution alternatives, rather than a single general resolution. Each specific advisory contains sufficient information to formulate the appropriate clearance for the aircraft involved.

If the controller accepts one of the suggested resolutions (rather than independently generating a resolution), the accepted resolution will be translated into a correct clearance and transmitted by data-link to the aircraft, if it is properly equipped. The clearance will be displayed to the controller first, however, and will not be transmitted until approved.

Other functions introduced in previous AERA packages will also be enhanced in this stage. Most significantly, the Long Range Probe function is expected to have evolved by this stage into a fully automated decision tool for the controller. Data on expected and historical traffic flows will be evaluated by the automation in order to inform the controller of any anticipated control problems beyond the range of the Flight Plan Conflict Probe.

It is also expected that in this stage of AERA development the metering plan will be incorporated into the trajectory when it is generated, without requiring specific approval from the controller.

By AERA 2.02, the Conflict Alert function will also be enhanced to consider more information from the aircraft's flight plan and trajectory than it does in the present ATC system. Because only radar track data is considered today, NAS Conflict Alert does not know about planned turns, and must assume that the aircraft will maintain its current heading; this leads to false alarms and delayed detections when one or both aircraft are turning.

An enhanced Conflict Alert, called the Separation Assurance Monitoring function, will use trajectory information to modify the track data to reflect expected turns or altitude changes. Separation Assurance Monitoring will present two different alert messages to the

controller: a high-level alert, if the track data as modified by the trajectory indicates a conflict, or a low-level alert, if only the track data indicates a conflict. The latter case would indicate to the controller a situation which was not expected to present a conflict, but which could lead to a separation violation if the aircraft did not follow their expected trajectories.

AERA 2.03

This AERA package represents the last stage before AERA 3. Consequently, the ATC functions which will be fully automated in AERA 3 will all be present in AERA 2.03, but with the human controller still making the final decision in each case.

This characteristic of AERA 2.03 is reflected in each functional area. Only one specific resolution advisory is presented to the controller, representing the best course of action that the software could determine. Upon approval by the controller, the resolution is transmitted as a clearance to the properly-equipped aircraft. Data-link transmission occurs in veto mode: unless the controller takes specific action to expedite, hold, or cancel the clearance, it will be transmitted a specified time after being displayed.

The planning functions of AERA are fully integrated by this stage, so that the resolution advisories presented may address multiple control problems at the same time. For example, a conflict resolution maneuver may help to resolve more than one conflict, or may incorporate metering goals as well.

Deviations from the planned maneuvers, and deviations from the expected trajectories, were detected in previous AERA packages and displayed to the controller. In AERA 2.03, resolutions for these deviations are generated and displayed for controller approval. The resolutions may take the form of new clearances for the aircraft or amendments to the aircraft's flight plan as needed to restore agreement between the aircraft's actual and expected performance.

AERA 3

AERA 3 represents the goal for the effort to automate en route Air Traffic Control. In this stage of development, the automation functions are expected to detect and resolve many routine ATC problems automatically, and act to implement those resolutions. The controller will not need to be fully involved with such routine situations, but will have a greater capability for maintaining an overall control plan and dealing with less routine problems.

In most cases, the specific controller approval required in AERA 2.03 will no longer be necessary. The controller will, however, have the option to intercede at any time. The controller will receive prior notification of control actions which are planned by the automation, as feasible, and will be able to request additional detailed information if desired. Actions planned by the automation system may be modified or cancelled, and the planning tools will exist to help the controller to investigate alternative actions.

Although the controller still has the ultimate responsibility, it is anticipated that the resolutions generated by the system will be implemented in most cases. Consequently, the maneuvers generated for conflict resolution or for deviation correction will be incorporated into the trajectory as they are generated, to keep the trajectory as current as possible.

CONCLUSION

This report presents a series of descriptions of the AERA packages as currently envisioned. Both operational and functional characteristics are discussed: what the functions are intended to do, and how they are expected to interact with the controller and other ATC functions.

This document is not intended to be a formal description of a fully developed system. There are many unresolved issues remaining, and much research and analysis to be done. Nevertheless, the publication of this material is appropriate at this time to document the current design of AERA, to provide information useful to the design of the AAS, and to stimulate discussion. Revisions to these descriptions are certain as the development of AERA continues.

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LIST OF ILLUSTRATIONS

1. INTRODUCTION

The Federal Aviation Administration (FAA) is currently in the process of developing a new computer system, called the Advanced Automation System (AAS), to help control the nation's air traffic. The AAS will consist of new or enhanced hardware (i.e., Central Processing Units, memories, and terminals) and new software.

The new software will retain most or all of the functions in the existing NAS (National Airspace System) En Route Stage A software, but recoded and possibly using different algorithms. In addition, the new AAS software will contain several new functions that make greater use of the capabilities of automation for Air Traffic Control (ATC). These new functions will represent the initial implementation of the concept known as AERA.

1.1 Evolution of ATC Automation

AERA is an integral part of the FAA's overall twenty-year plan for improvements to the nation's air traffic control system. This plan, as set forth in the National Airspace System Plan [1], calls for enhancements and upgrades to the en route and terminal control systems; flight services; and navigation, communication, and surveillance systems.

Replacement of the computers currently used for air traffic control is one of the early features of the NAS Plan. New "host" computers will be installed which will support the existing NAS Stage A software with minimal changes. Additionally, the improved speed and capacity of the host computers will allow the implementation of several software functions currently under development, such as Conflict Resolution Advisories and En Route Metering II.

After the host computers are installed, new work stations for controllers and supervisors, known as Sector Suites, will be introduced in the field. In addition to providing the controller with a larger and improved display of the traffic situation, the Sector Suites will include interactive displays for data entry and electronic presentation of flight data currently printed on paper flight strips.

The new hardware of the AAS will then be installed, either as a replacement or an extension of the host computers. The new AAS software, incorporating the first AERA functions, will be an integral part of the AAS implementation.

When fully implemented, the AERA functions are intended to detect and resolve many routine ATC problems automatically, and act to implement those resolutions. It is expected that the controller will need not be fully involved with such routine situations, and will thus have a greater capability for maintaining an overall control plan and dealing with less routine problems. The result is planned to be a significantly enhanced control capability, with benefits for airspace users and increased levels of controller productivity and safety.

The AERA functions will be introduced as a series of packages to provide a staged evolution of capability. The problem detection functions are to be implemented first, to provide benefits to the airspace users, followed by the resolution functions for enhanced controller productivity. AERA will initially appear to the controller as a set of planning tools to help move traffic more effectively, but it will develop into an automated decision-making system. While such full automation of the air traffic control process may never occur, it is the goal to be described in this paper.

1.2 Benefits of Advanced ATC Automation

There are three principal benefits to be attained by providing additional automation assistance to the air traffic controller:

- increased services to the users
- increased controller productivity
- improved system safety

The present-day ATC system contains examples of procedural restrictions which are necessary for the controller to be able to handle the existing traffic levels safely, but which impose constraints on the aircraft and pilots who use the system. These restrictions tend to regularize the flow of traffic and limit variations between aircraft to acceptable levels. The proper automation functions could greatly reduce the need for restrictions and increase the flexibility of the air traffic control system to accommodate the desires of the airspace users. For example, it might be less important for all aircraft to fly on the known, published routes if automation aids were available to provide timely detection of conflicts between any two aircraft, on published routes or not.

These procedural restrictions tend to reduce the capacity of the airspace. A goal of the AERA automation features is to enable controllers to handle additional traffic by employing automation

functions, rather than procedural restrictions, to deal with traffic conflicts.

This is the second benefit of additional ATC automation: increased controller productivity. Increased controller productivity can be achieved through any of the following changes. The number of aircraft per sector could be increased, the size of the sector could be increased, or the number of controllers per sector team could be decreased.

The automated functions can increase controller productivity by making the control task easier and by reducing the need for involvement in certain control tasks. Controller workload for a given traffic level is expected to be reduced by providing more planning assistance to the controller, thereby allowing a structured and more uniform level of workload for the controller.

Certain controller tasks can also be eliminated or eased considerably by automation. For example, much verbal coordination between controllers was eliminated by the "silent handoffs" in NAS, whereby handoffs between sectors were initiated automatically and conducted by use of simple accept/acknowledge pushbutton actions. Similarly, it is expected that the new automation functions of AERA can further improve verbal coordination between controllers. For example, verbal discussion of a problem could be supplemented by information on the problem which is available from the automation and sent automatically between controllers. Other coordination is required today to detect potential problems in the other controller's sector, which may be done more efficiently by the automated probe functions.

Lastly, but most importantly, additional ATC automation is expected to make beneficial contributions to the safety of the air traffic control system. By improving the ability of the controller to monitor traffic and detect potential problems and by providing additional planning capability, the new automation functions are expected to reduce the frequency of separation violations between aircraft and between aircraft and terrain. The reduced need for coordination between controllers also reduces the possibility of poor communication, one of the main causes of operational errors in the ATC System (see Appendix G of "The Human Element in Air Traffic Control: Factors in System Recovery and Revitalization" [2].)

1.3 Purpose and Scope of This Document

These benefits of advanced ATC automation are to be obtained through the implementation of the AERA concept. The highest level of benefits would come from the highest degree of automation, but the FAA recognizes that a completely automated ATC system cannot be implemented immediately. Aside from the technical challenges, there are possible problems of safety, controller training, and controller acceptance if the ATC system is automated too quickly.

Consequently, implementation of the AERA functions is planned to occur in a series of stages. Each stage of development, or "package" of features, would provide for additional automation capability in several functional areas in a manner which enhances the capabilities of the system as a whole. This series of AERA packages was described in the MITRE report "Evolution of Advanced ATC Automation Functions" [3], which presented the rationale for the particular functions and enhancements in each package.

The work described in this report provides additional detail for the package descriptions in that report. The AERA packages, as defined in the MITRE report, were investigated with special attention to:

- How the new functions and enhancements interface with each other and with other functions of the ATC system.

- How the controller will be affected by the new functions, and how they can be used to control traffic.

The functional and operational descriptions, respectively, will discuss the results in these areas.

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1.4 Structure of This Document

Before the functional and operational descriptions of the AERA packages are presented, an overview of the process of AERA evolution is presented in Section 2. The reasons for an

evolutionary approach to AERA are discussed briefly, followed by the guidelines which were used to derive the specific characteristics of the AERA packages. An overview of these packages is then given. Last, Section 2 describes the approach which was taken in developing the operational and functional descriptions.

The descriptions then follow, with a separate section devoted to each AERA package. Section 3 thus discusses AERA 1.01, Section 4 describes AERA 1.02, and so on. Within each section, the relevant differences between that package and the previous one are presented, together with a brief evaluation of the significance of the enhancements. This is followed by a description of the interfaces between AERA functions and with other ATC functions, as they are affected by the new and enhanced functions. The interaction with the controller, and the effect of the new and enhanced functions on the controller in the performance of his duties, are then given in the operational description.

After all six AERA packages are described, Section 9 gives a brief summary and conclusion for the report.

2. OVERVIEW OF ADVANCED AUTOMATION EVOLUTION

This section presents an overview of the planned evolution of the advanced automation functions in the air traffic control system, from the present day NAS Stage A through full automation in AERA 3. These packages were originally described in "Evolution of Advanced ATC Automation Functions" [3], and the characteristics of the packages described therein have not been substantially altered in this report. The principal characteristics of each package are largely determined by the overall goals and guidelines which were assumed for the advanced automation; those goals and guidelines are discussed below.

2.1 Goals of Staged Evolution

2.1.1 Benefits of an Evolutionary Approach

As described in "The AERA Concept" [4], the objective of the AERA automation program is to improve the ATC system by applying a high degree of automation to routine ATC situations. This would mean that the ATC computer would anticipate control problems, generate resolution actions, and implement these actions with only a minimum level of involvement by the controller. The controller would be expected to continue as an active participant in the control process, but on a higher level of involvement: setting the overall control strategy and dealing with non-routine situations, perhaps, while overseeing the routine performance of the automation.

This high level of automation is a major increase beyond the capabilities of the current ATC system. There are basically two alternative approaches for implementing this advanced automation: either all at once or as a series of increments.

Introducing full automation in a single step would be a significant and abrupt change in the process of air traffic control. A considerable amount of new training would be required for the controllers to make use of the new functions and to adapt their procedures to changes in the existing functions. The changes would be so extensive that the new system could just as easily be completely independent of the present system. This would allow considerable freedom in designing the usage of the new system which could result in a better system of automation.

Any change to the ATC system is thoroughly tested before being implemented in the field. Even so, further revisions are frequently required as a result of unforeseen operational

requirements or field conditions which were not adequately considered. A radical change to the ATC system, such as a switch from NAS Stage A to full AERA, would be subject to extremely extensive testing, but even then problems might arise in the field, and reverting back to the previous system would be very difficult.

However, if the new functions were introduced incrementally, each step could be proven in the field before the next package of automation is introduced. With proper design, existing functions would be little changed by the introduction of the new automation features, making it easier to temporarily revert to the previous system in the event of operational problems with the new features.

Other possible advantages of the gradual transition to full automation include reduced developmental risk and improved controller confidence. For all these reasons, a strategy of gradual evolution was followed in developing the following set of AERA packages.

2.1.2 Evolution Strategy

Several guidelines were utilized in developing the specifics of the following automation packages.

Each package is intended to provide a tangible improvement in operational capability compared to the previous one. This means that each step offers benefits to the controller or the user, or both, without penalizing or degrading the operation of any of the previously existing functions.

Each automation package consists of a number of separate functional enhancements, designed to operate in coordination. Nevertheless, there is considerable design and operational flexibility inherent in each of the following packages, allowing for changes to the development or implementation of the packages if necessary. Each package represents a complete and stable system that could form the basis for the next incremental package, or could if necessary support the ATC system without further enhancements.

The evolutionary stages of AERA can be characterized by an increasing level of automation. The first two steps, comprising AERA 1, provide problem-detection and planning tools for the controller's use. The features of AERA 1 will provide most of the benefits to the airspace users to be derived from advanced automation. The steps of AERA 2 introduce computer-aided

problem resolution as well, with increasingly specific resolutions. Increased controller productivity is expected as a result of AERA 2. Finally, in AERA 3, computer-aided implementation of selected resolutions are implemented in the form of automatic transmission of the resolution to the involved aircraft.

This increasing level of automation is made possible in part by the improving quality of data made available to the planning functions. This is due partly to improvements in the automation algorithms and partly to enhancements external to the automation functions, such as improved surveillance sensors. However, the main factor in improving the data quality will be improved interactions between the automation functions. Improved predictions about the future position of the aircraft allow for more accurate detection of control problems such as conflicts. This in turn allows for the earlier resolution of these problems and encourages the controller to specify to the system more of the control plan for each aircraft (i.e., the long range strategy for integrating that aircraft into the overall flow of traffic, including metering goals and aircraft priorities). With this improved information come still more accurate predictions of position, problems, and resolutions. There is, therefore, a cumulative effect on the accuracy of the AERA processes, as the functions are implemented.

2.2 Description of the AERA Packages

Figure 2-1 presents a simplified overview of the development of the AERA packages. In this diagram, each vertical column represents a separate stage of automation; enhancements to the functional areas are arrayed horizontally, from left to right.

The initial package of advanced automation features, referred to as AERA 1.01, will be implemented as part of the initial Advanced Automation System of hardware and software. AERA 1.01 will introduce automated planning tools which use the aircraft flight plan data, and will consist of four functions:

- Trajectory Estimation will calculate the flight path of the aircraft in three spatial dimensions (x,y,z) and time (t), based on information from flight plans and other sources.

- Flight Plan Conflict Probe will compare aircraft trajectories in order to test for conflicts between aircraft, situations in which separation minima are predicted to be violated.

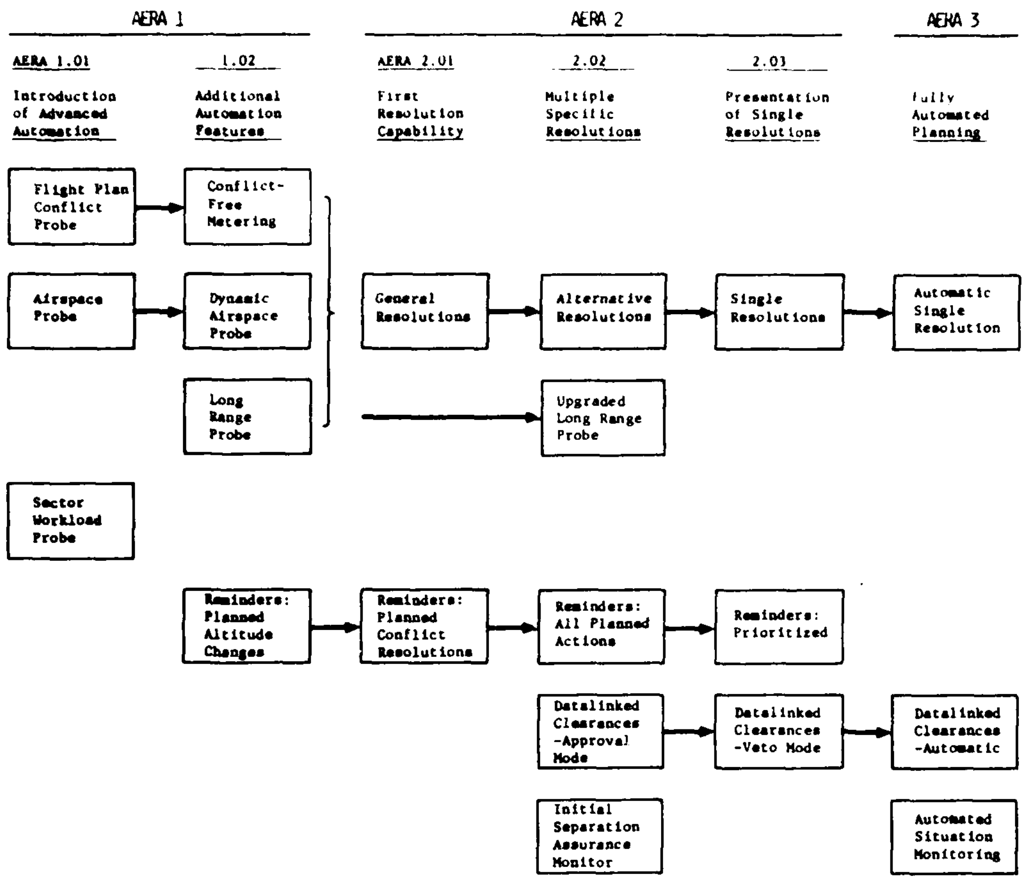

FIGURE 2-1
OVERVIEW OF THE AERA PACKAGES

- Airspace Probe will use the aircraft trajectory to test for conflicts with specific static adapted airspace volumes (special use areas and terrain).

- Sector Workload Probe will display various workload-related measures to supervisory personnel to assist in determining sector manning levels and/or resectorizing as necessary to balance workload.

AERA 1.02 will add several new functions and will integrate the advanced planning functions more closely with the existing functions. A Long Range Probe capability will be added to help the controller evaluate off-airway route requests which extend beyond the prediction horizon of the Conflict Probe. The Airspace Probe will be enhanced to consider conflicts with dynamic weather areas as well as with static areas of special-use airspace. Metering advisories to the controller will be checked for potential conflicts before being displayed. The controller will be able to make more of the overall control plan known to the automation system, which in turn will provide reminders of planned actions at the appropriate times.

In AERA 2, these functions will be enhanced to improve controller productivity. Three steps are planned for AERA 2. The first, AERA 2.01, will introduce a computer capability for helping the controller to resolve those problems detected by the other advanced automation functions. Initially, this capability will consist of general advisories presented to the controller, with the controller adding the necessary details. For example, the resolution advisory could indicate the aircraft involved in a conflict and the appropriate resolution maneuver, such as a climb, but leave it to the controller to specify the final altitude assignment. As these conflict resolutions are made known to the system by the controller, the system can help remind the controller to execute the different steps of the resolution at the appropriate time.

AERA 2.02 will see further enhancements to the resolution capability. The controller will be presented with several specific, complete resolutions; if one is selected, and the aircraft is datalink-equipped, the resolution will be automatically converted into a clearance to be datalinked to the aircraft upon approval. This package will also include enhancements to the NAS Conflict Alert function, to reduce the occurrence of false alarms by considering information about aircraft intent, as appropriate, as well as radar track data.

This enhanced function is termed the Separation Assurance Monitor.

The next automation package sets the stage for the fully automated ATC system referred to as AERA 3. In AERA 2.03, only a single resolution is displayed to the controller. If the resolution is approved, it is translated into a clearance which is presented to the controller and automatically datalinked to the equipped aircraft unless specifically vetoed by the controller. The resolutions and reminders are assigned priorities by the system, based upon a global planning perspective.

Finally, full automation is applied to the ATC system in AERA 3, allowing routine planning and resolution actions to be conducted without controller intervention.

2.3 Approach

The above survey of the AERA packages has been provided in order to establish a sense of how the ATC system is seen to develop over time with the introduction of the automated functions, and how the individual packages contribute to the goal of full ATC automation. In the following sections, the individual packages will be discussed in greater detail. In particular, a functional and operational description of each package will be presented.

The functional description is the "behind-the-panel" view of the automation. Some details may be given on the processing techniques and algorithms of each function, but the main emphasis will be on the role of each particular function within the overall ATC automation system. The flow of information and control between functions will be discussed on a high level. Details of timing, protocols, exact control sequences, and other important items will need to be left unaddressed until the functions are further developed.

In contrast to the functional description, the operational description of the AERA packages presents the functions as they appear to the controller. The operational description discusses:

- When and how the AERA functions may be invoked.
- What information should pass between the controller and the system.
- The effect of the automated functions on the controller's actions.

- How the controller is to integrate the new functions into the process of controlling air traffic.

In order to avoid unnecessary duplication, the following *operational and functional* descriptions will only discuss the new features of each package and the associated changes to the ATC system. Any aspects of the ATC automation which are not discussed may be assumed to have not changed significantly compared to the previous AERA package. As a result of this approach to the descriptions, the following sections, taken individually, are not complete descriptions of the ATC system at the time each package is implemented; rather, the descriptions are cumulative, building upon previous sections in the same way each new package builds upon the previous AERA packages.

Since these systems have not yet been implemented, the functional and operational descriptions are only conceptual. However, they are based upon a familiarity with the current ATC system and with the current state of AERA development. The resulting descriptions are subject to change as more is learned about the AERA functions and as development proceeds, but at the present time these descriptions should provide the best available information on the AERA packages.

It is expected that more complete descriptions of the individual AERA packages will be produced as part of the developmental process. The first package, AERA 1.01, has already been described in the MITRE report "Operational and Functional Description of AERA 1.01" [5].

3. AERA 1.01

The first AERA features to be implemented are contained in the package referred to as AERA 1.01. This package will be installed as part of the initial Advanced Automation System of hardware and software.

3.1 Enhancement Features

AERA 1.01 consists of four automation features:

- Trajectory Estimation
- Flight Plan Conflict Probe
- Airspace Probe
- Sector Workload Probe

The following section briefly describes the role of each of these functions.

3.1.1 Trajectory Estimation

NAS Stage A includes a Route Conversion function which checks the filed horizontal route of flight for validity, substitutes applicable preferential routes, expands the route to include intermediate fixes, and determines the Calculated Time of Arrival (CTA) at each fix.

The Trajectory Estimation (TJE) function in AERA 1.01 augments the Route Conversion function to provide more accurate four-dimensional (4-D) flight path estimates, called "trajectories." Information from the aircraft's cleared flight plan through the ACF airspace is supplemented with available information about winds and temperatures aloft and other information from the AAS data base to produce a series of points in x, y, z, and t that define the aircraft's path. The aircraft's desired climb/descent profile will be used, as known, to estimate its vertical trajectory.

Amendments to a flight plan will trigger a reconversion (if needed) and reestimation of the balance of the flight's trajectory. If the difference between an aircraft's trajectory and its radar track position exceeds a parameter, as determined by the Conformance Monitoring function (which is similar to the Flight Plan Association Checking task in NAS), an adjustment is made to the estimate of the aircraft's speed (based on the radar track history) to account for the error prior to reestimating the trajectory from the aircraft's present position. This is referred to as "resynchronization."

The Trajectory Estimation function is critical to the successful implementation of AERA, since the probes require more accurate trajectory information than is available from NAS Stage A, especially in the vertical dimension.

The importance of an accurate trajectory to the operation of the AERA control functions requires that TJE be supplied with the most current data on expected aircraft performance as identified by the aircraft's current clearances. The controller's compliance in following what are considered today to be good control practices (in terms of entering amendment messages when new clearances are given and maintaining conformity between the aircraft and its cleared route) is critical to the accuracy of the trajectories and thereby, the accuracy of the other planning and control functions.

3.1.2 Flight Plan Conflict Probe

The Flight Plan Conflict Probe (FPCP) function compares the trajectories of aircraft within the ACF Planning Region to detect future situations in which applicable separation criteria between aircraft may be violated. FPCP automatically monitors all trajectories within the Planning Region, which extends beyond the boundaries of the ACF to ensure thorough coverage of all flights.

The Conflict Alert function plays a similar role in NAS Stage A, but with some important differences. Conflict Alert uses radar track data, independent of the flight plan, to detect possible violations of radar separation criteria within the next two minutes. Flight Plan Conflict Probe, as its name implies, uses flight plan information to detect possible separation violations as long as twenty minutes or more in advance.

The Flight Plan Conflict Probe function is triggered automatically, and may also be invoked directly by the controller to probe a trial amendment for the aircraft. This capability is referred to as the Trial Plan Probe (TPP). The goal of Trial Plan Probe is to allow the controller the flexibility of testing various changes to a flight plan without changing the data base or committing the aircraft to unneeded plan modifications.

In the later AERA packages, the performance of the Flight Plan Conflict Probe is expected to be improved as a result of additional data, refinements to the algorithms, and enhancements to other functions. In addition, resolutions to

the detected conflicts will be generated automatically in the later packages.

3.1.3 Airspace Probe

Adapted within the data base of each en route facility's computer system are airspace volumes designated as Restricted Areas, Military Operation Areas, Warning Areas, etc. These designated special use airspaces have an altitude floor and ceiling, specific geographic boundaries, and times of activation/deactivation associated with them. Most aircraft are required to avoid these areas. Such airspace polygons can also be used to define terrain to be avoided.

The Airspace Probe (AP) function is designed to probe a flight throughout the Planning Region of the ACF to detect violations of the designated airspaces. If an airspace conflict is detected, a conflict message will be generated and displayed to the appropriate controller.

The Airspace Probe function will be particularly useful in processing requests for off-airway User-Preferred Routes (UPRs), for the early detection of conflicts with special use airspace by direct flights and other UPRs. In later AERA packages, this function will be enhanced to allow detection of conflicts with dynamic airspace regions, such as severe weather areas. A resolution capability will also be provided.

3.1.4 Sector Workload Probe

As an aid to managing the workload associated with the traffic peaks in a center, a method of predicting some workload-related measures at the sector level has been included in the AAS Specification [6]. Sector Workload Probe computes these estimated measures and displays them to the Area Supervisor or Area Manager who can use them to help with decisions on sector manning or combining/decombining sectors.

The workload measures are calculated for successive time intervals up to a limit (e.g., for each fifteen minutes over the next hour). They include:

- the aircraft count in the sector
- a weighted sum of anticipated ATC actions (such as procedural altitude changes, speed reductions, and handoffs)

- a count of encounters that have been detected by the Flight Plan Conflict Probe and Airspace Probe functions

- a measure of traffic density

3.1.5 Other Automation Enhancements

In addition to the AERA 1.01 features, the AAS software will include several automation functions which are not available in the present NAS Stage A. Some of these functions are being developed at this time, and will be installed in the "host" computers; others have been specified in the AAS Specification [6] to be part of the initial AAS software.

These functions will include the following:

- Improvements to En Route Metering--NAS Stage A includes the first version of En Route Metering, ERM I, which computes and displays the delay to be absorbed by specific flights. ERM II, which gives the controller advisories on the most fuel-efficient means to absorb that delay, will be introduced with the host computers. In the AAS, this function will be enhanced to allow metering of flights to any fix or boundary, as well as to an airport metering fix.

- Conflict Resolution Advisories--The CRA function provides the controller with a display of possible alternatives for the resolution of conflicts between controlled aircraft, as detected by the Conflict Alert function. In the AAS, this function will be enhanced to also generate alternative resolutions for conflicts detected with terrain and special use airspace.

- IFR-VFR Conflict Alert--This function extends the Conflict Alert function to all pairings of Mode C equipped uncontrolled (VFR) aircraft with controlled (IFR) aircraft in en route airspace.

In addition to these functions, all the automation functions of NAS Stage A are assumed to be available in the AAS as well, although details of processing or presentation may differ. The AERA 1.01 functions are, for the most part, additions to these functions rather than replacements for them.

3.2 Functional Description

In order to describe the functions and interfaces for each AERA package, the AERA-related functions in the AAS have been organized into several functional areas. In the following sections, this organization will be discussed first, followed by the descriptions of each functional area in AERA 1.01.

3.2.1 Organization of the AERA Functions

For the purposes of this document, the AERA-related automation functions can be categorized as either Planning Functions or Control Functions. The Planning Functions help to organize and control traffic with a time horizon of 20 minutes or so; these functions are therefore strategic aids to the sector controller. The Control Functions are more concerned with implementing the strategic plan and dealing with problems that are more tactical in nature, with a shorter time horizon (e.g., five minutes or less).

The Planning Function category consists of the following functional areas:

- Trajectory Estimation--constructs the four-dimensional estimate of the aircraft's expected trajectory.

- Problems Prediction--encompasses the Flight Plan Conflict Probe, the Airspace Probe, Long-Range Probe, and Metering Prediction.

- Solutions Planning--contains the automated planners, such as Metering Planning, Conflict Resolution Planning and Deviation Resolution Planning in later packages. These planners control the automatic addition of Planned Actions to an aircraft's trajectory to accomplish various planning objectives.

The following functional areas are considered under the heading of Control Functions:

- Plan Implementation--contains the functions that carry out the intent of the AERA planning functions. Plan Implementation functions include Conformance Monitoring and Tactical Execution.

- Tactical Problem Detection--monitors the real-time situation in the AERA control region to identify tactical

control problems, primarily using radar track data. Detected conflict situations are presented to the controller for evaluation/action. The functions include the Separation Assurance Monitor and Airspace Violation Detection.

- Tactical Problem Resolution--determines corrective actions required to resolve near term violations of aircraft separation standards and airspace conflicts.

Each functional area consist of one or more specific functions. A consistent set of functional areas will be used in this report to characterize the different AERA packages, although the functions within each area will be enhanced and new functions will be added as AERA evolves. These functional areas will be used to describe the relations between the AERA functions and between AERA and other ATC automation. As such, they represent general capabilities of the ATC automation rather than specific software modules.

Figure 3-1 illustrates the internal components of AERA 1.01. The components on the left side of the diagram represent the Planning Functions, and the components on the right represent the Control Functions. The elements within the dashed lines are those elements of 1.01 which are AERA-related. The diagram is intended to show the relationships of the components to each other and to other, external elements of the ATC system. It is not intended to show sequence of processing actions. In the discussion of each component, its place in the processing sequence will be discussed.

3.2.2 Trajectory Estimation

An algorithmic specification for Trajectory Estimation [7] has been developed. "Trajectory Estimation," used as the name of the specification, logically groups three functions: Trajectory Estimation and two ancillary functions that feed Trajectory Estimation called Nominal Plan Builder and Resynchronization.

In NAS Stage A, the Route Conversion function alters pilot-requested routes to conform to established preferential routes in terminal areas. Nominal Plan Builder provides an analogous service in the vertical dimension, interpreting stored data on established ATC procedures in order to predict the aircraft's vertical profile.

Trajectory Estimation constructs a four-dimensional (4-D) ground referenced path, or trajectory, for each flight plan it receives. These trajectories are based upon the aircraft's cleared flight plan and a list of "Planned Actions" which reflect pilot intents implied by the flight plan, and controller intents either implied by routine ATC procedures or explicitly made known by the controller. Four types of planned actions are supported in AERA 1.01:

- Altitude change (possibly with restrictions)
- Speed change
- Fully-specified vectors
- Hold at a fix

The trajectories also include consideration of the effects of winds and temperatures aloft and atmospheric pressure.

The Resynchronization function supports the resynchronization process. The internal estimate of the aircraft's ground speed is modified to account for discrepancies between the aircraft's observed speed and its flight plan speed, which may be due to errors in the stored wind values used for the calculation. Trajectory Estimation then recomputes the trajectory.

The modeled trajectory is composed of an ordered list of points representing a 4-D estimate of aircraft position at all locations along the cleared route of flight within the Planning Region. The output of TJE (the completed aircraft trajectory) is accessed by the components requiring the trajectory as input.

3.2.2.1 Execution Stimuli

Trajectory Estimation will be activated whenever a trajectory must be created or revised, including automatic updates.

A request to remodel an amended or revised flight plan may be generated as a result of a controller input or automatically by the Conformance Monitoring function, when a longitudinal error of sufficient magnitude is detected between the tracked position of the aircraft and its trajectory. A lateral or vertical deviation will be detected by the automation and indicated to the controller, as in NAS Stage A, but it will be the controller's responsibility to restore conformance with the trajectory.

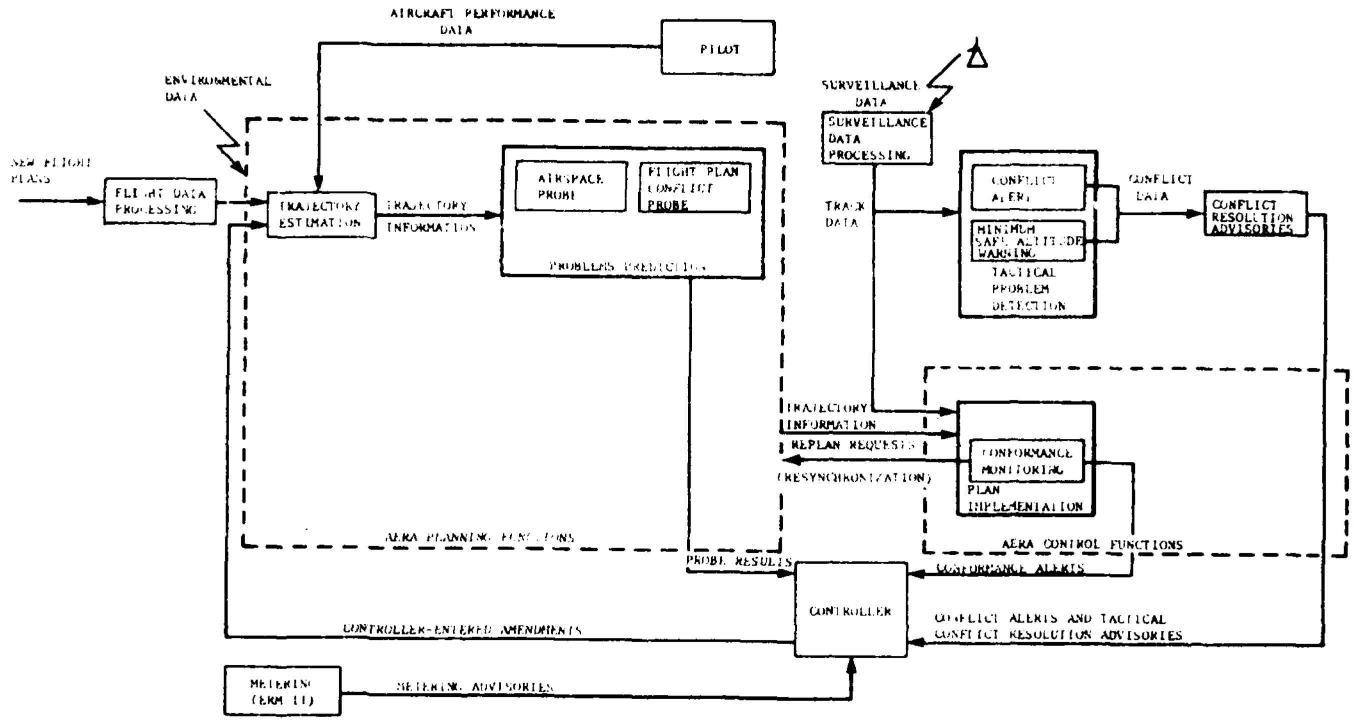

FIGURE 3-1
FUNCTIONAL COMPONENTS – AERA 1.01

3.2.2.2 External Interfaces

Trajectory Estimation receives information on flight plans, aircraft performance characteristics, and meteorological conditions from other automation functions and system data bases.

Information on new flights or current flights with route amendments is received from the AAS Route Conversion function in the form of processed flight plans. The converted plan is a horizontal route plan which consists of the pilot's original filed plan, modified to accommodate established procedures such as preferential routes (PDARs, PARs, etc.) or Severe Weather Avoidance Plans, and then translated into a sequence of (x,y) points.

Aircraft performance data is used by TJE to create a trajectory based on the expected performance of a particular aircraft or class of aircraft. In AERA 1.01, the performance data may consist of general characteristics per aircraft type (e.g., climb and descent gradients, minimum and maximum speeds, etc.) obtained from manufacturer's specifications and airlines' operational procedures. Data on individual aircraft will also be maintained, as available. TJE will use the best available data in calculating trajectories.

The Trajectory Estimation process also makes use of weather information when constructing trajectories. This information (winds and temperatures aloft) is obtained from the Central Weather Processor (CWP), which has consolidated information from the National Weather Service (NWS), pilot reports, and other sources. In later stages of AERA, the Trajectory Estimation process may provide feedback on wind information. Wind error accumulation information, deduced from aircraft deviation data, would be supplied to the Center Weather Service Unit (CWSU) for evaluation and possible use.

Input to Trajectory Estimation is also obtained from the controller. The controller is responsible for updating the trajectory data to reflect all clearances given to, and acknowledged by, aircraft under his control. This is done by entering flight plan amendment messages whenever a change is made to the aircraft's currently cleared flight plan. Input of these messages is an extremely important interface because it keeps the projected trajectories in close correspondence with the ATC clearances as known by the pilot, which is necessary for the probe functions to detect conflicts.

If the trajectory is not kept up to date, the aircraft's expected position may not be accurate and the probes may be compromised since they will not have access to valid trajectories. Whether or not the probes should operate on invalid trajectories, such as out-of-conformance aircraft or aircraft on vectors which have not been incorporated into the trajectory, will need to be resolved. On the one hand, the trajectory is known to be invalid, but on the other hand, it represents the best information known to the system. Operations involving invalid trajectories would need to be specially flagged to alert the controller.

The controller does not normally receive output directly from the Trajectory Estimation function, except when display of an aircraft's trajectory is specifically requested. Trajectory information might also be displayed in connection with a detected conflict, or other output of another automation function.

3.2.2.3 Internal Interfaces

Trajectory Estimation and its ancillary functions do not receive input data from any of the other AERA 1.01 functions; all of the input comes from external sources, as described above. The other three AERA 1.01 functions receive the trajectories from TJE as part of their input. Flight Plan Conflict Probe and Airspace Probe use the trajectories to detect future violations of separation standards; Sector Workload Probe uses the trajectories to derive expected traffic levels and characteristics.

3.2.3 Problems Prediction

The functional area of "Problems Prediction" includes functions whose purpose is to detect situations which must be brought to the attention of a controller or supervisor or presented to the automated system for resolution. In AERA 1.01, these functions include Flight Plan Conflict Probe, Airspace Probe, and Sector Workload Probe. More information is available in the algorithmic specifications for these functions [8,9,10].

Flight Plan Conflict Probe uses a coarse filtering process to eliminate those trajectories that are too far removed from that of the subject aircraft to be considered in further prediction processing. A fine filter is then employed to determine if the applicable separation criteria will be violated. If so, the predicted violation is classified as an "encounter," and a description of the violation is stored. Not all encounters

immediately meet the criteria for display to a controller (the predicted violation may be too far off in the future, for example). At the proper time, information concerning the encounter will be displayed to the appropriate controller(s) for attention.

Airspace Probe compares the trajectory of the subject aircraft against all airspace and terrain polygons. As in FPCP, a coarse filtering process is implemented to quickly eliminate those polygons which are not in close proximity to the aircraft's flight path. A fine filter then tests for actual intersection of the polygons by the flight path, taking into account applicable altitude bounds and activation times of each polygon. Any violation thus detected is displayed to the controller at the appropriate time.

3.2.3.1 Execution Stimuli

Flight Plan Conflict Probe and Airspace Probe are activated to probe for conflicts for an aircraft when the trajectory for that aircraft is first created and whenever the trajectory is modified, including resynchronization updates.

Sector Workload Probe will execute upon receipt of an immediate supervisor request for data, or at regular intervals. It will update its information upon a resectorization, when a new flight plan is added to the system, or when an existing plan is modified.

3.2.3.2 External Interfaces

The principal external interface for these three functions is with the human element of the ATC system, the controller and the supervisor.

The controller will receive the conflict information processed by the conflict probes (Airspace Probe and Flight Plan Conflict Probe). Identification of detected conflicts is to be presented on the controller's displays. Additional information regarding a particular conflict situation may be available to the controller upon request, and may include a graphic display of the conflict situation.

The controller will be able to initiate a probe for a specific aircraft either by entering a flight plan amendment or a trial amendment. These inputs are processed by Trajectory Estimation and therefore are not direct interfaces with the Problems Prediction functions.

The supervisor will interface with the Sector Workload Probe to obtain workload information for a particular sector or sectors. This information is displayed as a result of either an immediate request from the supervisor or a supervisor-programmed request. Output to the supervisor consists of the presentation of the information from the Sector Workload Probe in the form of sector-specific reports, covering specified time intervals. Sector Workload Probe also makes use of data from an external source regarding sector characteristics.

Similarly, in order to detect violations of special use airspace or conflicts with terrain, the Airspace Probe requires definition of the special use areas by an external source. This data consists of such characteristics as identification of the areas (e.g., by name or number), a geographic description of the polygons representing the areas, activation times, and applicable altitudes. The designated airspaces (Restricted Areas, Military Operation Areas, Warning Areas, MSAW polygons, etc.) are adapted with an altitude floor and ceiling, specific geographic boundaries, the times of activation/deactivation and other identifying information.

3.2.3.3 Internal Interfaces

All three of the problem prediction functions receive aircraft trajectories from TJE as part of their inputs. These trajectories are accessed as required by the individual functions.

Additionally, Sector Workload Probe uses the conflict information from Airspace Probe and from Flight Plan Conflict Probe. It has no internal AERA interface for its output, but other users such as display processors may access the data.

3.2.4 Solutions Planning

The components of AERA 1.01 do not include any functions which perform resolution planning themselves, although they do provide the controller with planning tools (such as the Trial Plan Probe). A metering capability does exist within the Air Traffic Control system at the time of AERA 1.01, but it is not an AERA function. According to the AAS Specification [6], the AAS will allow metering to any fix or boundary, according to a rate, separation, or schedule.

The metering capability will be integrated with the other automation functions in later AERA packages.

3.2.5 Plan Implementation

The Plan Implementation area is composed of two main functions: Conformance Monitoring and Tactical Execution.

The Conformance Monitoring function in AERA 1.01 is not functionally different from Flight Plan Association Checking in today's NAS Stage A. The track position of the controlled aircraft is periodically compared with its expected position according to its cleared flight plan. If the longitudinal deviation along the route exceeds a (system parameter) value, arrival times along the route are recalculated (through the resynchronization process, in AERA). If the lateral deviation exceeds a parameter, or if the aircraft deviates from its assigned altitude, this is indicated on the controller's Situation Display, as in NAS today.

The Tactical Execution functional component includes notification to the controller that a previously-planned action should begin, and monitoring during the maneuver for conformance. In the AERA 1.01 time frame, only the Metering function provides advisories to the controller concerning the start of a maneuver, and Metering is not an AERA 1.01 function. The other duties of Tactical Execution are performed by the controller without automation assistance.

3.2.6 Tactical Problem Detection

In AERA 1.01, this functional area consists of the Conflict Alert and Minimum Safe Altitude Warning (MSAW) functions of NAS Stage A, which use radar track data to detect imminent violations of separation criteria between aircraft, and between aircraft and airspace respectively. These functions will be enhanced in the AAS, but are not properly considered AERA functions.

These functions are activated by the receipt (from the Radar Data Processing function) of new track data, on each tracking cycle, for each of the aircraft in the Planning Region. Any conflicts detected are reported to the controller, along with the associated Conflict Resolution Advisories (from the pre-AAS CRA function). Conflict Alert and MSAW results are not used by any of the other major AERA-related components, and these functions do not use any information from those components.

3.2.7 Tactical Problem Resolution

Once again, in AERA 1.01 there are no AERA-related functions within this functional area. The Conflict Resolution Advisory (CRA) function will have been implemented in the pre-AAS host computers to generate and display alternative resolutions for the conflicts detected by the Conflict Alert and MSAW function.

3.3 Operational Description

One of the most important interfaces of the AERA 1.01 functions is with the human element of the ATC system, the controllers and supervisors. Some of the data flows from the functions to the human element have already been mentioned. The following paragraphs will discuss how that data may be used by controllers and supervisors in performing their tasks, how the new functions provide new control tools, and the possible impact of those tools on the controller's and supervisor's responsibilities.

For this discussion, an air traffic control tool will be defined as an automated aid which is visible to the controller and which assists in performing control tasks. Four new tools will be introduced by AERA 1.01:

- Flight Plan Conflict Probe
- Airspace Probe
- Sector Workload Probe (for supervisors)
- Trial Plan Probe

Three of these tools are directly linked by name to three of the new functions of the AAS. The fourth tool, Trial Plan Probe (TPP), allows the controller to submit a proposed flight plan amendment for testing by the Flight Plan Conflict Probe and Airspace Probe function.

Since Trajectory Estimation is not directly visible to the controller, it will not be discussed in this operational description. The controller does interact with this function, but only in the context of other activities, e.g., through flight plan amendment messages, as in NAS, or the output of the conflict probe functions.

3.3.1 Flight Plan Conflict Probe

3.3.1.1 Stimulus

The Flight Plan Conflict Probe operates whenever an aircraft trajectory is changed, as explained in Section 3.2.2. FPCP creates a list of aircraft "encounters," in which two trajectories have been determined to violate separation criteria at some time in the future.

Once an encounter is displayed to the controller, it may be considered to be a conflict. In today's ATC system, a "conflict" is any situation in which applicable separation criteria may or will be violated. With today's non-automated methods of conflict prediction, conflicts are detected, for the most part, when the predicted point of violation occurs within the sector in which the involved aircraft are flying or within the adjacent sector. The controller is directed to resolve conflicts promptly.

The automated probes add a new dimension to the definition of "conflicts" by detecting situations in which separation minima may be violated much further in the future. Though these situations fit the current definition of "conflict," they are different from "conflicts" detected in NAS Stage A in two important ways. First, because of the longer lookahead times, the estimates of future aircraft position are more subject to variations in winds and aircraft performance, and thus there may be less certainty that a separation violation will occur if no control action is taken. Second, the long lead time may reduce the need for prompt resolution. Requiring the controller to resolve such situations promptly may therefore increase workload without significantly increasing system safety. It is therefore useful to create a new category of "possible problem areas" to include these situations which do <u>not require</u> prompt resolution.

Consequently, AERA will consider two different classes of conflicts. "Priority Conflicts" would be detected as conflicts by the controller today, and require prompt resolution by the controller. An "Advisory Conflict," on the other hand, is less immediate and is presented to the controller for information only. The controller may choose to act to resolve an Advisory Conflict, or may elect to defer action, allowing for the possibility that the perceived conflict may "resolve itself" as the trajectories are updated. The Advisory Conflict will be automatically upgraded to priority status at the appropriate

time, or if trajectories are updated and the situation then fits the parameters of a "Priority Conflict."

3.3.1.2 Information Displayed

The two types of conflicts, Advisory and Priority, are identified to the controller through advisory and priority messages, respectively. These messages may be sent to the "involved" controllers, where an "involved" controller is one who meets one or more of the following criteria:

- The controller has computer control of one or both of the aircraft involved.
- The controller is in radio contact with one or both of the aircraft involved, if this is known to the AAS.
- One or both of the aircraft is in the controller's airspace.
- The predicted point of violation is in the controller's airspace.

Particularly in complex situations such as ones in which the aircraft involved are currently in different sectors and the predicted point of violation is in a third sector, the issue of who gets the advisory or priority message is non-trivial and a subject for study.

Both the advisory and priority messages contain information necessary for the controller to identify the Advisory Conflict, such as identification of aircraft involved, location of predicted violation, time of violation, and IDs of sectors with current control of the aircraft involved. Additional information may be available to the controller via an alternate display, e.g., a graphical representation of the situation.

A control directive will be required to assign responsibility for initiating required coordination and for resolving the Priority Conflict. In most cases it is expected that the priority message will be sent to the controller in whose sector the violation is predicted to occur, and possibly to other involved controllers. The assignment of responsibility is subject to modification and elaboration as a result of further study.

3.3.1.3 Controller's Response

The controller's responsibilities in AERA 1.01 will be defined by control directives to be developed. It is expected, however, that the controller's responsibility with respect to any Priority Conflict, whether it is detected by an automated probe or by mental monitoring activities of the controller, will be to resolve it promptly. The Flight Plan Conflict Probe will provide information on the conflicts detected that will assist the controller in forming resolutions. The responsibility for resolution will remain with the controller.

With regard to Advisory Conflicts, it is expected that the controller will be required by directives to verify and evaluate the detected situation. The advisory message is primarily a notice to the controller to be aware of and monitor the situation closely because it may develop into a Priority Conflict. The controller may optionally take measures to resolve the situation, but such measures would probably be considered only as an additional service.

The advantages of displaying Advisory Conflicts are related to the additional time provided to the controller by the early detection of possible problems. Early detection gives the controller more time to develop alternative resolutions and allows certain resolutions (such as speed adjustments) which require a longer time to produce the desired result.

3.3.2 Airspace Probe

3.3.2.1 Stimulus

The Airspace Probe is invoked whenever an aircraft trajectory is changed, as is FPCP. The new aircraft trajectory is checked for violations of any static airspace regions which may define special use airspace, such as Restricted Areas or Prohibited Areas, or which define minimum altitudes for flight above terrain. Airspace Probe may also be invoked if an airspace region is activated by a supervisory action, i.e., if a region which was previously available to flights becomes unavailable. In this case, many trajectories would be processed sequentially by the Airspace Probe.

The controller will not necessarily be aware of the reason why Airspace Probe was invoked.

3.3.2.2 Information Displayed

When Airspace Probe detects a violation of a protected airspace region, the characteristics of the violation are noted and presented to the controller at the appropriate time. As with aircraft conflicts, there are two types of airspace conflicts, advisory and priority, depending on factors such as time until violation. An Advisory Airspace Conflict will result in an advisory message to the controller; a Priority Airspace Conflict will produce a priority message. In both the advisory and priority messages, the controller is presented with information which helps to identify the conflict and formulate a resolution, such as aircraft ID and identification of the violated airspace. Additional information regarding the conflict may be available to the controller upon request, including possible graphic display of the conflict situation.

3.3.2.3 Controller Response

The controller's responsibility in the AAS with respect to special use airspace is unchanged. The controller must clear nonparticipating aircraft via routing which will provide approved separation from the special use airspace, unless clearance of nonparticipating aircraft in or through the area is provided for in a Memorandum or Letter of Agreement. It is the pilot's responsibility to be aware of areas of special use airspace and, unless permission to enter an area has been granted by the using agency of the area, to structure his flight plan such that these areas are avoided.

Since the Airspace Probe examines the entire path of an aircraft through the Planning Region, situations in which separation minima may be violated may be detected considerably in advance of the predicted violation (similar to Advisory Conflicts). This advance notice of possible airspace conflicts has two implications:

- Very early coordination with the pilot may be effected, to allow the pilot to resolve the problem (since he has primary responsibility for avoiding reserved airspace).

- Resolution of the problem may be deferred (because of controller workload) until the aircraft is within proximity of the sector in which the airspace conflict occurs.

If an airspace conflict is detected more than a stated (system parameter) number of minutes before the predicted violation, an

Airspace Violation advisory message is sent to the controller then in control of the aircraft (or about to be in control if the aircraft has not yet entered the center). The controller's responsibility with respect to an Airspace Violation advisory message will probably be to treat the pilot notification as an additional service. If time and workload conditions permit, the controller will do one of the following:

- advise the pilot of the problem.
- approve/disapprove pilot-suggested plan amendment (if the pilot offers an amendment).
- if assistance is requested by the pilot, suggest a plan amendment which resolves the problem.

The controller will need to indicate to the system that the pilot was notified. This tells the system that no more messages need be given to subsequent controllers until a priority message is required (unless the predicted violation has been resolved). If, on the other hand, the controller receiving the message is unable to respond to it and the aircraft is handed off to the next sector, the controller for that sector will also receive an Airspace Violation advisory message. This will continue until either a controller acknowledges the message or until the conflict is close enough in time that an Airspace Violation priority message is sent.

The purpose of the Airspace Violation priority message is to inform the controller that an aircraft which is currently under his control has a conflict with an area of special-use airspace or with terrain. The message is sent to the involved controller(s), even if the previous advisory messages had been acknowledged and turned off by the controller. The responsibility of the controller is to determine if the aircraft should be permitted to enter the specified airspace, and if permission is not to be given, to provide the pilot with routing around the airspace.

3.3.3 Trial Plan Probe

3.3.3.1 Stimulus

The Trial Plan Probe is activated by the controller to perform a Flight Plan Conflict Probe and an Airspace Probe on a proposed trial flight plan amendment. Although the Trial Plan Probe is, in a sense, composed of these other two functions, it

is considered to be a separate controller tool because it is invoked differently and produces different output from the other two functions, and serves a different purpose.

Flight Plan Conflict Probe and Airspace Probe are monitoring functions, operating in the background to detect problems automatically. The controller only knows they are working when they present advisory or priority messages on his display. Trial Plan Probe, on the other hand, is directly usable by the controller. TPP is a planning tool, not a monitor, which assists the controller in determining whether a trial plan would resolve any previously-identified conflicts and/or create new conflicts. An example of a typical situation for use of the Trial Plan Probe would be in responding to a pilot request for an off-airway segment.

3.3.3.2 Information Displayed

The Trial Plan Probe identifies "potential conflicts," i.e., conflicts involving the trial plan of the subject aircraft with the current trajectories of other aircraft or with special use airspace.

Trial plans will most likely be input into the computer in the same manner that all other flight plan amendments will be input by the controller, such as through the interactive display that is one of the components of the Sector Suite. When the controller has finished amending the plan and has verified that it is entered into the computer as intended, the probe will run automatically without further controller intervention. The results of the probe are presented only to the controller who initiated it.

If a potential conflict is detected by the probe, the controller will be presented with a message which contains information necessary to identify the potential conflict. This information is the same as that presented to the controller when a real conflict is detected by the automated probes, but should clearly identify the conflict as being related to a trial plan. If the Trial Plan Probe detects no potential conflicts, the controller will be explicitly so informed.

3.3.3.3 Controller Response

The controller uses the results of the probe and knowledge of the current situation to decide whether or not to implement the trial plan. If the controller decides to implement the trial plan, the controller will transmit an appropriate clearance to

the pilot and receive an acknowledgment. The controller will then indicate to the computer that the trial plan is to be accepted as the current plan. If it is determined that the trial plan is unacceptable, the controller could reject it and repeat the evaluation process with an alternative plan.

3.3.4 Sector Workload Probe

3.3.4.1 Stimulus

The Sector Workload Probe (SWP) is intended to aid supervisory personnel such as Area Supervisors and Area Managers in planning and conducting positional manning and combining/decombining sectors. The supervisor can specify the conditions under which SWP will be invoked to present new or updated values of the workload-related parameters. SWP may be invoked on immediate request of the supervisor, at regular intervals (e.g., every five minutes), or when specified workload measures pass threshold values set by the supervisor.

3.3.4.2 Information Displayed

The probe information displayed to the supervisor shows the current and estimated future values of certain workload-related measures for each sector. The information for each sector may include data for various time periods in the future up to the limit of the probe function.

The following data for each sector will be provided by SWP:

- the current and anticipated number of aircraft
- the current and anticipated number of conflicts
- some "weighted" sum of anticipated planned actions related to the number of clearance changes to be issued
- the current and anticipated density of the traffic flow
- the current and anticipated aggregate value of the workload measures

The supervisor will be able to specify the format and content of the information to be displayed. The time periods and the particular sectors for which the information applies will also be selectable by the supervisor.

3.3.4.3 Supervisor Response

It will be the responsibility of the supervisor or manager to interpret the significance of the different categories of information and determine the manner in which to use the information. By comparing the expected sector workload with the current sector workload, the supervisor can determine whether or not sectors need to be combined or decombined, or whether sector manning changes are needed. Such decisions will be based upon experience and according to ATC rules and directives.

4. AERA 1.02

AERA 1.02 is the second of the transition steps, and as part of the package known as AERA 1, its enhancements focus mainly on problem-detection and planning tools. AERA 1.02 adds several new functions and integrates the advanced functions mo_: closely with the other automation functions. The following specific enhancements are discussed below:

- Long Range Probe
- Dynamic Airspace Probe
- Conflict-Free Metering
- Controller Reminders

Several other enhancements are also discussed.

4.1 Enhancement Features

4.1.1 Long Range Probe

The Long Range Probe is a new automated tool available in AERA 1.02 that assists the sector controller in evaluating requests for off-airway User-Preferred Routes (UPRs) by detecting problems beyond the range of FPCP.

Current difficulties in approving UPRs include the controller's lack of knowledge about the traffic flows and densities beyond the sector boundaries, and about the ATC preferred route structure that may be unnecessarily applied to the UPR. The Long Range Probe is intended to provide the controller with information about areas of high traffic density which might affect the UPR, as well as to facilitate the efficient application of ATC-preferred routes. The process for accomplishing this may involve the designation, by appropriate supervisory personnel, of "protected airspace" around busy traffic flows which would be avoided by the UPR. Automation aids also may be introduced to help establish and implement "preferred routes" to avoid the high-density areas.

4.1.2 Dynamic Airspace Probe

The Airspace Probe function is expanded in AERA 1.02 to detect conflicts between aircraft trajectories and dynamic airspace, primarily heavy weather areas. In AERA 1.01, the Airspace Probe predicted conflicts only with static special use airspace

and terrain protection regions. In this package, the probe can detect additional possible problem areas by comparing aircraft trajectories with forecasts of future weather patterns made by external sources. This is the first automated tool for helping the controller to predict conflicts between aircraft and weather cells.

The current methods available to the controller for identifying aircraft encounters with weather are limited due to lack of current weather data and the difficulty of predicting future weather patterns. The controller's knowledge of severe weather areas is derived mainly from pilot reports that are based on visual observations and on-board weather radar. The Air Route Surveillance Radar is designed to suppress weather information and concentrate on aircraft data. The Center Weather Service Unit (CWSU) gathers and analyzes available meteorological information, but the dissemination of weather data and expected forecasts to the controllers needs improvement.

The brunt of responsibility for avoidance of weather cells, icing, and turbulence falls on the pilot, with minimal assistance from the controller. The controller's directives only require the controller to assist the pilot, where possible, in detection and avoidance of severe weather (see Air Traffic Controller's Handbook, paragraphs 40, 50 [11]).

In AERA 1.02, the controller is in an improved position to assist the pilot in detecting and avoiding severe weather areas. The controller will have available for relay to the pilot detailed information concerning the weather area, such as precipitation levels, wind velocities, and turbulence levels. This information is provided to the controller by the NEXRAD (NEXt-generation RADar) system, which is a major improvement to the ATC system to be implemented prior to AERA 1.02. The Dynamic Airspace Probe allows the controller to provide the pilot with advance warning of encounters with severe weather. With the detailed weather data from NEXRAD, the controller will not only be able to help the pilot detect possible problem areas, but also identify effective maneuvers for avoidance of the areas.

NEXRAD will also provide data to the CWSU to be integrated with other weather data (e.g., from the National Weather Service) and used to formulate forecasts of future weather patterns for the center. These forecasts will be available from the CWSU and Central Weather Processor (CWP) for use by the Dynamic Airspace Probe.

4.1.3 Conflict-Free Metering

Among the major features of AERA 1.02 is the generation of conflict-free metering advisories. When an aircraft must be delayed, the Metering Planning function generates a conflict-free maneuver for the aircraft that will absorb the required amount of delay, and displays this information to the controller in an advisory message. Should the advisory be unacceptable to the controller, alternative conflict-free advisories are available on request.

It is important to understand the scope of the term "conflict-free" as it applies to metering. The advisories generated by the Metering Planning function will not lead to conflicts prior to the metering fix (i.e., the geographic point which the aircraft is to cross at a specified time), insofar as can be determined by the automated probes. The segments of the aircraft's trajectory before the start of the maneuver and after the maneuver is completed are not guaranteed to be conflict-free since they are beyond the scope of Metering Planning. (The merging of the Conflict Resolution function and Metering Planning is a later enhancement.) Additionally, aircraft not considered by the probes (out-of-conformance, VFR aircraft, etc.) are not taken into account by Metering Planning.

Earlier versions of the metering function (ERM I and ERM II) provided assistance in the generation of an initial metering plan, but subsequent tasks of probing for potential conflicts within the plan and development of alternative plans, if necessary, were left to the controller.

The improvements to the metering function in AERA 1.02 represent a major step toward complete automation of the controller's metering activities. Since the advisories are conflict-free (as determined by the probes) and recommend an effective, feasible way of absorbing the required delay (based on experience gained in earlier versions) it is expected that the controller will accept the advisories as they are presented. In this case only the transmittal of the clearance to the pilot remains in the controller's domain, and in future automation packages the transmittal will also be automated. If the controller determines, for a reason undiscernible by the probes, that the advisory is unsatisfactory, the automated function will continue to provide assistance to the controller in the form of alternate advisories.

4.1.4 Controller Reminders

To maximize the validity and utility of the automated probes of the AAS, it is essential for an aircraft's trajectory, which is the basis for all of the probes, to reflect the most current control plan for the aircraft. In AERA 1.02, a mechanism for providing additional feedback to the controller about the internal version of the control plan is introduced in the form of Controller Reminder messages. By reminding the controller of control actions that he had planned for particular aircraft, these messages help the controller to implement the previously agreed-to plan, or to identify any existing differences from the controller's current plan. The controller may then update the trajectory for the aircraft to accurately reflect the current plan.

Strategic control plans can be entered into the computer in one of two ways in this automation package. First, certain control actions, such as descent to the destination airport, are implied by an aircraft's flight plan and are incorporated into the aircraft's trajectory automatically when the flight plan is initiated. The second way is through explicit controller messages, first available in AERA 1.02, that allow the controller to specify a control action to be implemented at some known time in the future, such as a step climb to a new cruise altitude, but which is not part of the aircraft's current clearance. This information will also be incorporated into the aircraft's trajectory since it will improve the accuracy of the trajectory for predicting future aircraft positions.

The major significance of the controller-entered strategic Planned Actions and the Controller Reminder messages is the improvement to the Trajectory Estimation function and thereby all the other automation functions that are based on the trajectory. The more detailed knowledge of the controller's control plan for an aircraft allows the aircraft's position to be more accurately predicted, an essential input for valid and effective probes. While AERA 1.02 handles only planned altitude changes, future automation packages will deal with additional planned actions, to eventually include all actions related to control of aircraft.

4.2 Functional Description

The functional components of AERA 1.02 and their interfaces are depicted in Figure 4-1.

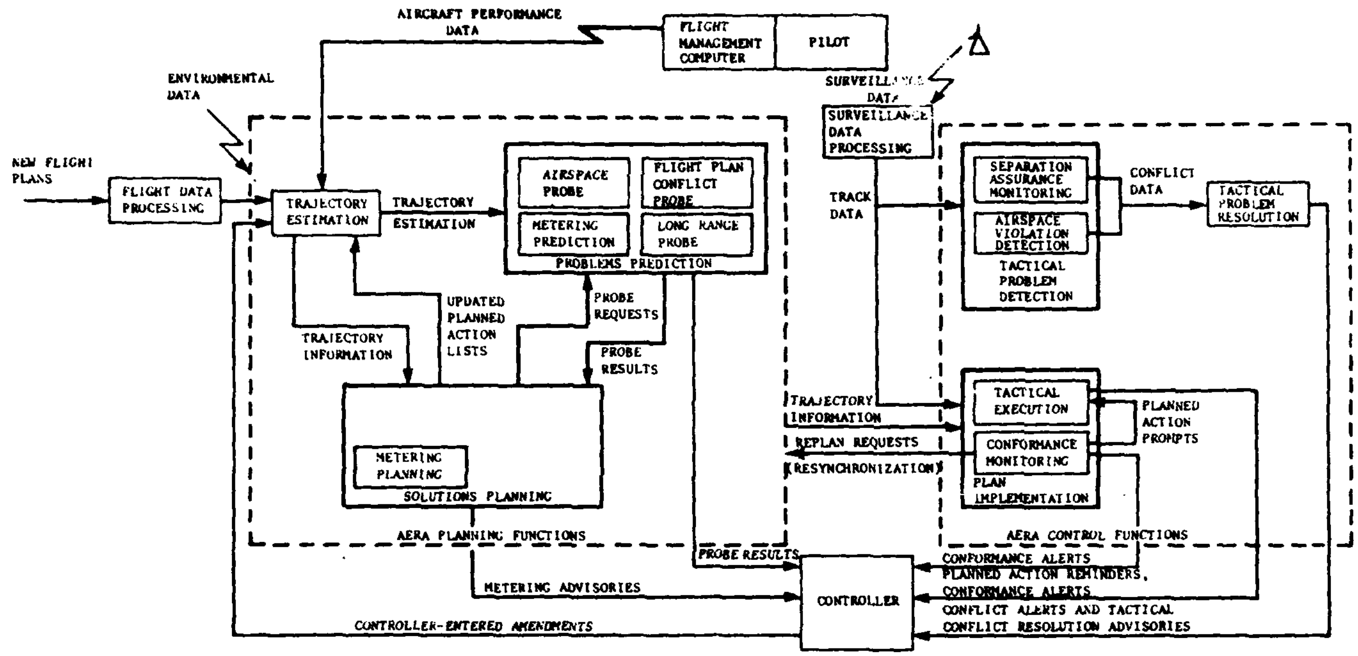

FIGURE 4-1
FUNCTIONAL COMPONENTS – AERA 1.02

4.2.1 Trajectory Estimation

In AERA 1.02, Trajectory Estimation is enhanced to include the capability to model goal-oriented Metering Planned Actions i.e., planned maneuvers which are intended to deliver the aircraft to a given location at a given time, but which do not completely specify how that goal will be reached. Thus, in addition to the four planned actions already supported by Trajectory Estimation in AERA 1.01, the following new ones are added:

- Metered descent
- Metering vector
- Metering speed change

In addition to these enhancements, additional aircraft performance data may be available for some aircraft by direct downlink from the aircraft Flight Management Computer. This additional information will be taken into account when the trajectory is modeled. (It should be noted that, while the result is a trajectory which more closely reflects the intent of the aircraft, this is the result of better data, not changes in Trajectory Estimation.)

4.2.1.1 Execution Stimuli

As in AERA 1.01, Trajectory Estimation is activated when a new or revised plan is received from the Route Conversion function; the controller inputs a plan amendment; or the Conformance Monitoring function indicates the need for resynchronization. Two new events can occur in AERA 1.02 that will also trigger the activation of Trajectory Estimation:

- Metering Planning generates one or more Metering Planned Actions for a flight and requests that these planned actions be incorporated into the trajectory.

- Trajectory Estimation is called to update a trajectory to reflect updated aircraft performance data.

4.2.1.2 External Interfaces

The only conceptual change in external interfaces is the updating of new aircraft performance data (which, in fact, will probably be transparent to the internal processing of Trajectory Estimation). This new performance data, downlinked from the aircraft, consists of items which reflect a change in

the manner in which the pilot intends to follow his cleared plan (e.g., a different climb or descent gradient).

An example of this would be a new gradient or speed schedule to be used for a particular altitude transition. If it is known in advance of the transition that a gradient other than the nominal will be used, the incorporation of that information into the trajectory at the earliest point in time will provide the benefits of more accurate prediction of conflicts.

The other external interfaces with Trajectory Estimation are unchanged from AERA 1.01. These include weather information (winds aloft, temperatures aloft), adaptation information applicable to the Planning Region (for example, Standard Operating Procedures and Letters of Agreement) and processed flight plans from the Route Conversion function (both new plans and existing plans with route amendments).

4.2.1.3 Internal Interfaces

The internal interfaces new to AERA 1.02 are the requests for incorporation of Metering Planned Actions into the aircraft trajectories (from the Metering Planning function of the Solutions Planning component) and the output of completed trajectories to the Metering Planning and the Long Range Probe functions. Other internal interfaces from AERA 1.01 remain unchanged: the output of trajectories to the other Problems Prediction functions, and requests from Conformance Monitoring to resynchronize a trajectory.

4.2.2 Problems Prediction

For the purpose of describing the system in terms of large, functional areas, it is convenient to group together several functions in the category of "Problems Prediction." Three of the functions, Flight Plan Conflict Probe, Airspace Probe, and Sector Workload Probe, are familiar from AERA 1.01. Two additional functions, Long Range Probe and Metering Prediction, are included in the Problems Prediction area for AERA 1.02. Figure 4-2 illustrates the relationships of these five elements to each other and to other system components.

4.2.2.1 Execution Stimuli

Both Flight Plan Conflict Probe and Airspace Probe are activated to probe for conflicts whenever a trajectory is first constructed or is updated. In AERA 1.02, the probes will be activated following a trajectory update required to incorporate

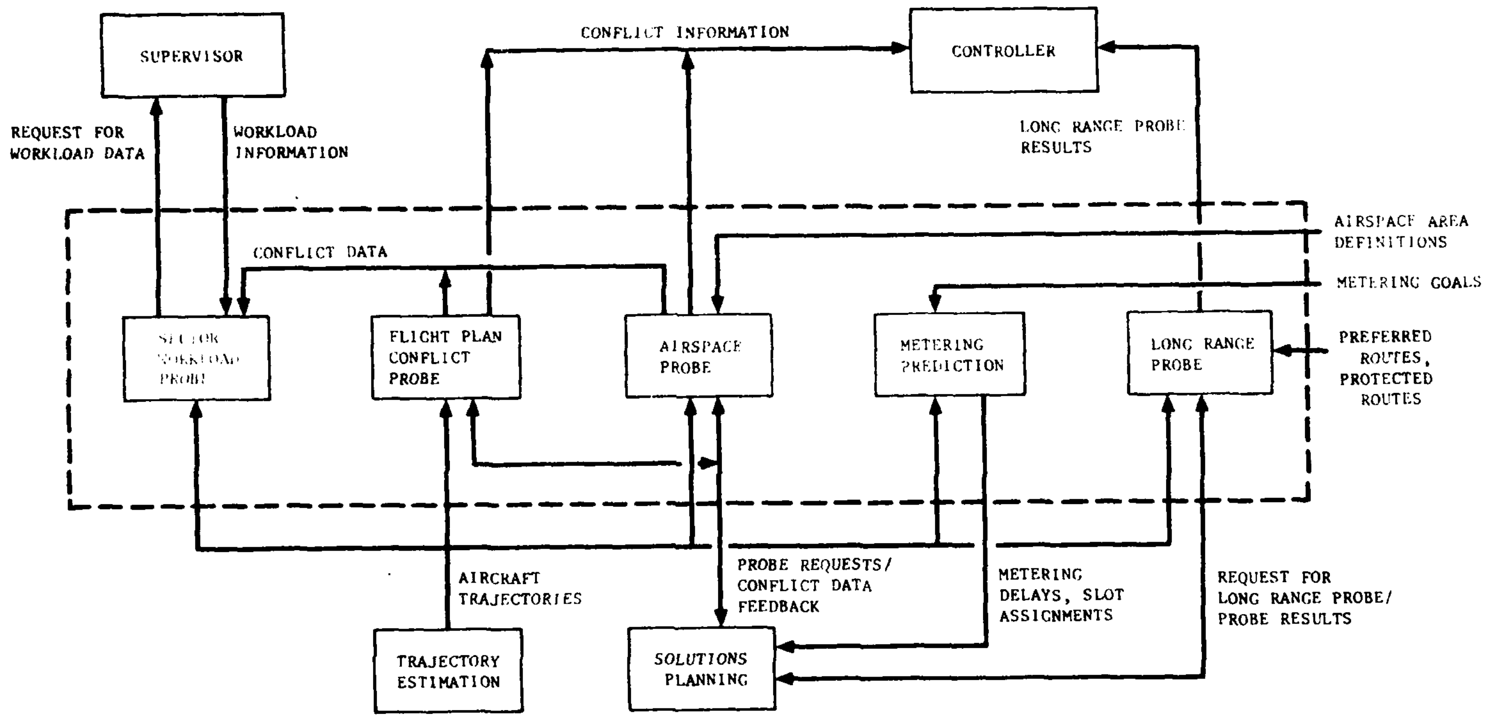

FIGURE 4-2
PROBLEMS PREDICTION COMPONENT

new aircraft performance data, such as downlinked descent profile information for a particular descent. They may also be called upon to probe a trial plan formulated by Metering Planning.

Airspace probe is also initiated whenever an area of special use airspace is activated or deactivated, or whenever the definition of a weather area is added or updated (e.g., the boundaries of the area change or the predicted velocity is changed).

Metering Prediction is activated whenever a new trajectory is constructed or when an existing trajectory is updated. The Long Range Probe is activated when a new off-airway flight plan is received or when the route of a current flight plan is amended to include an off-airway segment. The Sector Workload Probe is triggered by a request from the supervisor for workload information.

4.2.2.2 External Interfaces

The functions in the Problems Prediction area have a number of external interfaces. The Long Range Probe uses information on traffic densities and preferred routes input by appropriate supervisory personnel at the center, and the results of the probe are presented to the controller. The Airspace Probe requires a definition of the weather areas and special use areas that must be provided by external sources. In addition, the output from both Flight Plan Conflict Probe and Airspace Probe is presented to the controller in AERA 1.02 as it was in AERA 1.01. The only external interface to Metering Prediction is the specification of the metering goals. These goals will be provided by such sources as the Flow Controller at the ACF or a neighboring terminal facility, or perhaps by the sector controller. The goals may be specified in one of the following formats:

- arrival rate at a location (where "location" may be a fix or boundary)
- arrival separation at a location (e.g., 5 minutes apart, or 25 miles apart)
- a specific schedule for arrival at the location

4.2.2.3 Internal Interfaces

All five of the Problems Prediction functions utilize the aircraft trajectories constructed by Trajectory Estimation. These trajectories are accessed by the individual functions as required.

The Solutions Planning component generates a request to Metering Prediction to determine if metering is required for a particular plan. If it is necessary to insert a Metering Planned Action into the plan, the Flight Plan Conflict Probe and Airspace Probe are requested to probe a trajectory after a Metering Planned Action has been incorporated. Since that metering plan is a trial plan until approved by the controller, the results of the probes are returned to the Solutions Planning component for evaluation, rather than being presented to the controller.

The Solutions Planning component also generates a request for the Long Range Probe to examine a plan for possible interaction with areas of high traffic density, or with ATC-preferred routes (although the decision to incorporate those routes is made by the controller, not the Solutions Planning functions).

4.2.3 Solutions Planning

This functional area represents those functions which participate in the process of planning modifications to a strategic flight plan. In AERA 1.02, we see the first introduction of an automatic strategic planning function, Metering Planning.

Metering Planning will meet the requirements of the ERM II package which was used in AERA 1.01; it will provide arrival rate metering to an airport and metering to a fix (not just meter fixes) or boundary. A crucial capability added in AERA 1.02 is the ability to integrate the metered plan with the AERA probes and thus be able to provide the controller with "conflict-free" metering.

Metering Planning is intended to ensure that the plans of aircraft requiring metering are adjusted with the appropriate planned actions to absorb the required delay and meet the (externally imposed) metering objectives. The delay absorption tools available to the planner are the new goal-oriented planned actions and the "Hold" Planned Action available in AERA 1.01.

After the total amount of delay to be absorbed by a flight is determined by Metering Prediction, Metering Planner examines the total delay and decides how to distribute that delay over the plan. Typically, several maneuvers are used to absorb larger amounts of delay. For example, it may be planned for an aircraft to execute a speed reduction to Maximum Endurance Speed (MES), followed by a vector to absorb more delay, and finally meeting the total required delay through use of an idle thrust descent. In this case, these ATC actions would be represented on the aircraft's trajectory by the metered speed, metering vector and metered descent Planned Actions.

Having decided which maneuvers to use and how much delay they each absorb, Metering Planning then addresses the first maneuver. For AERA 1.02, Metering Planning deals with the maneuvers one at a time, i.e., each maneuver is modeled, ascertained to be conflict-free, and sent to the controller for approval and execution before subsequent maneuvers are modeled. Thus, only the earliest maneuver is modeled (as a trial plan) and sent to the conflict probes for prediction of conflicts. If conflicts are detected in the selected maneuver, the parameters of that planned action are adjusted or another type of planned action is selected. After adjusting the planned action, the plan is remodeled and again examined for conflicts. This continues until a conflict-free maneuver is found which absorbs the delay allocated to this maneuver. This Planned Action now represents the candidate metering advisory. In AERA 1.02, metering advisories are not presented to the controller until it is near the time to actually issue the clearance(s) to the aircraft, so Metering Planning does not (necessarily) immediately notify the controller of the advisory. When it is time to notify the controller, the plan must again be probed for conflicts, since other plans in the system may have changed, affecting the plan of the metering subject. If conflicts are detected at this point, the entire process of maneuver adjustment must be repeated until a conflict-free one is found. When the planned maneuver is determined to be conflict-free, it is presented to the controller.

When the maneuver is completed by the aircraft, Metering Planning is again activated to repeat the process with the remaining amount of delay to be absorbed. This continues until the final maneuver, which brings the aircraft to the metering objective by the proper time.

4.2.3.1 Execution Stimuli

Whenever a new flight plan is received or an existing plan receives an amendment, the plan is checked to determine if the flight requires metering. If metering is required for that flight, Metering Planning is activated to determine the type of maneuver and examine the results of incorporation of that maneuver (to ensure conflict-free manuevers, if possible). Metering Planning is also activated whenever the metering goals are changed, so that the Metering Planned Actions on the plan may be reevaluated. In addition, it will be triggered by a (longitudinal) resynchronization. New arrival times created by the resynchronization process may affect delay calculations, requiring update, replacement, or deletion of Metering Planned Actions.

In addition to these internal triggering events, Metering Planning may be invoked as a consequence of the controller's rejection of a presented metering advisory in order to try a different maneuver. If the controller requests a specific replacement maneuver with specified parameters, Metering Planning is activated to evaluate the proposed maneuver and report the metering consequences to the controller.

4.2.3.2 External Interfaces

Metering Planning's external interfaces are with the controller. In addition to the output to the controller of the probed metering advisory, Metering Planning may receive a request (from the controller) to try a metering maneuver other than the one originally presented. The new maneuver will be incorporated into a trial plan and the results presented to the controller.

4.2.3.3 Internal Interfaces

Metering Planning utilizes the aircraft trajectories from Trajectory Estimation in its planning processing. Output from the planner consists of requests to Trajectory Estimation to incorporate the generated Planned Action(s), as well as requests to the probe functions to predict problems with the new Planned Actions. Results from the probes are considered by Metering Planning when evaluating the effectiveness of a particular maneuver (before presentation of that maneuver to the controller as a metering advisory).

4.2.4 Plan Implementation

4.2.4.1 Conformance Monitoring

The Conformance Monitoring function within the Plan Implementation functional area monitors the progress of each aircraft with respect to its expected trajectory and planned ATC actions. It monitors only those dimensions (lateral, vertical, speed, time) for which the aircraft is not executing a maneuver. (Tactical Execution will monitor the maneuver dimensions.) Prior to AERA 1.02, significant lateral and vertical deviations from the trajectory are detected and reported to the controller; longitudinal deviations are detected and passed to the resynchronization function for automatic processing. Enhancements for AERA 1.02 consist of monitoring for conformance to the aircraft's cleared speed. Speed deviations, when detected, are presented to the controller for evaluation and processing.

4.2.4.1.1 Execution Stimuli

The Conformance Monitoring component is activated every tracking cycle to monitor for conformance of the aircraft's current tracked position to the strategic plan. Each tracking cycle, new radar data is obtained for all aircraft in the Planning Region, and the following processing is then performed.

The current tracked position of the aircraft is compared to the expected position described in the trajectory. If a sufficient longitudinal difference is detected, the resynchronization process is scheduled. If significant deviations in another dimension are detected, the controller is notified via alert messages (and perhaps also by other means, such as out-of-conformance indicators in the data block). In AERA 1.02, there is no automatic resolution of out-of-conformance conditions. (If the deviation is large enough, the controller may feel it is necessary to issue a new clearance to the aircraft. If this is done, a plan amendment message must be entered in order to keep the trajectory up to date with the new clearance(s) given to the aircraft.) The Conformance Monitoring function continues to monitor an out-of-conformance aircraft (although no more messages are sent). If the aircraft comes back into conformance, its internal status will be changed to reflect this.

The second main task of Conformance Monitoring is to monitor for planned action starts. The trajectory contains indications of when processing should be initiated for each planned action.

When a planned action start indicator is detected by Conformance Monitoring, a message is sent to the Tactical Execution (TEX) function, which then handles the processing of that planned action. From this point until processing of the planned action is complete, Conformance Monitoring performs association checking only in those dimensions not being monitored by TEX. When processing of the planned action is complete, Conformance Monitoring is activated fully by receipt of the "Planned Action Complete" message sent by Tactical Execution.

4.2.4.1.2 External Interfaces

New track data for each aircraft in the Planning Region is received by the Conformance Monitoring function from the Radar Processing component every tracking cycle.

Output from this component consists of deviation alert messages to the controller regarding out-of-conformance situations in the vertical, lateral, and speed dimensions.

4.2.4.1.3 Internal Interfaces

The trajectory constructed by Trajectory Estimation provides the basis for the comparison of tracked location vs. predicted location of an aircraft, as well as to determine when it is time to perform a *previously-planned* planned action. Conformance Monitoring also sends requests to Trajectory Estimation to resynchronize a trajectory. In addition, Conformance Monitoring notifies Tactical Execution when it is time to perform a planned maneuver (in the case of AERA 1.02, the only previously planned maneuvers are altitude changes and metering maneuvers), and Tactical Execution, in turn, notifies Conformance Monitoring when a maneuver has completed.

4.2.4.2 Tactical Execution

The purpose of the Tactical Execution function is to process the execution of planned actions. In AERA 1.02, this processing consists of the following:

- interaction with the controller, to provide notification of time to begin an Altitude Planned Action and to receive feedback from the controller regarding disposition of the planned action (approved/not approved)

- monitoring of the progress of the aircraft during execution of an altitude maneuver

- notification (to the controller) of significant deviations detected during the altitude maneuver

4.2.4.2.1 Execution Stimuli

TEX begins processing a planned action when it receives a "Start Planned Action" message from Conformance Monitoring. In AERA 1.02, this is done only for Altitude Planned Actions. The initial processing begins with notifying the controller of the pending planned action via a Controller Reminder message. The controller may approve further processing or decide against implementation of that particular planned action. (If that planned action is not to be implemented, the controller must enter the necessary amendment message(s) to keep the system apprised of his intentions.) Upon receipt of controller approval, Conformance Monitoring of the Altitude Planned Action begins. On each tracking cycle, the progress of the aircraft is compared to the intent of the planned action. Significant deviations from the intent (such as climbing during a Descent Planned Action or exceeding the assigned target altitude on a Climb Planned Action) are detected and an alert message is sent to the controller. All exception handling during execution of a planned action in AERA 1.02 is handled by the controller.

When execution of the planned action by the aircraft is complete, TEX terminates its processing by sending a "Planned Action Complete" message to the Conformance Monitoring component, which will then resume its own monitoring of the aircraft.

4.2.4.2.2 External Interfaces

Tactical Execution receives track data from the Radar Data Processing function to be used in monitoring for conformance to the altitude transition profile and in determining when the maneuver is completed.

It also provides several types of information to the controller: "reminders" that a previously planned maneuver was expected to begin now (for AERA 1.02, the maneuver would be an altitude transition) and deviation alerts (for AERA 1.02, only deviations from the vertical profile are detected). Responses from the controller regarding approval or rejection of these reminders are also received by TEX.

4.2.4.2.3 Internal Interfaces

Tactical Execution receives notification from the Conformance Monitoring function that a maneuver was planned to begin at the current time, and, upon completion of that maneuver, a message is sent to Conformance Monitoring informing it of the completion.

Although TEX does not use the trajectory as the conformance goal, it does use a description of the Altitude Planned Action in determining conformance to the intent of the planned action.

4.2.5 Tactical Problem Detection

The basic purpose of this component remains unchanged from the Conflict Alert and MSAW function of the current NAS system: to continually monitor the actual tracked positions of aircraft in the Planning Region to detect imminent conflicts. For AERA 1.02, two enhancements are added to the capabilities of this function: track information is supplemented with downlinked flight performance data (via Mode S), and imminent conflicts with dynamic airspace (weather) are detected. These enhanced functions will be referred to as Separation Assurance Monitoring and Airspace Violation Detection, respectively.

The downlinked flight performance data referred to here provides more immediate and more detailed information about the current state of the aircraft. An example of this would be such information as an indication from the aircraft that it is executing a turn. Receipt of this "turn indicator" provides Tactical Problem Detection with more immediate information about the current state of the aircraft than would have been obtained from track data alone (since the radar processing function will smooth out the radar returns before reporting that the aircraft is actually turning).

Processing within the Tactical Problem Detection component is functionally much the same as in today's system. The expected, near-term flight path of an aircraft is projected forward in time from the current tracked position, using the current velocity of the aircraft. The projected flight paths of all aircraft in the center are compared with each other in a pairwise fashion to determine if any of the pairs will violate separation minima. The flight paths are also checked for near-term intersection with predefined areas of special use airspace and heavy weather areas. When a conflict is predicted, the Tactical Problem Resolution component generates

a set of alternative resolutions (Conflict Resolution Advisories, introduced prior to the AAS) which are presented to the applicable sector controller along with identification of the conflict.

4.2.5.1 Execution Stimuli

The Tactical Problem Detection component is activated only by the receipt (from the Radar Data Processing function), on each tracking cycle, of new track data for each of the aircraft in the Planning Region.

4.2.5.2 External Interfaces

The new track data for each aircraft is received from a source external to the AERA functions (from the Radar Data Processing function), and this information is supplemented with downlinked performance data, if the aircraft is equipped with Mode S and other appropriate equipment. In addition, Airspace Violation Detection uses predetermined definitions of heavy weather areas and areas of special use airspace (stored in the system data base).

The results of the processing (notifications of predicted near-term conflicts between aircraft pairs, between aircraft and airspace areas, or between aircraft and weather areas) are reported to the applicable sector controller.

4.2.5.3 Internal Interfaces

Tactical Problem Detection results are not used by any of the other major AERA-related components except Tactical Problem Resolution, and Tactical Problem Detection does not itself use any information from those components.

4.2.6 Tactical Problem Resolution

No enhancement in this area occurs in AERA 1.02. As in AERA 1.01, Conflict Resolution Advisories are generated upon detection of an aircraft or airspace conflict by Tactical Problem Detection, and the advisories are presented to the controller for evaluation and selection.

4.3 Operational Description

4.3.1 Long Range Probe

4.3.1.1 Stimulus

There are three ways in which the Long Range Probe can be invoked. The principal method is through a Trial Plan Probe in which the controller proposes a User-Preferred Route. In this case, the Long Range Probe is run along with FPCP and AP, and its results are displayed simultaneously. The Long Range Probe is also invoked when a flight plan amendment containing an off-airway route segment is entered by the controller.

The third situation in which the Long Range Probe is invoked is when the information on areas of high traffic density, or ATC-preferred routes, is changed. This information may be updated by a supervisor-level controller, such as the Area Supervisor or the Flow Controller, based on input from the AERA data base and other automated aids. Alternatively, this information may be updated automatically. When the updating occurs, all affected flights are reconsidered by the probe, and the controller is notified of any detected problems.

4.3.1.2 Information Displayed

The message to the controller contains the nature and location of the detected problem. The results of the Long Range Probe are displayed to the controller on the Alert and Resolution logical display. If the probe was invoked within the Trial Plan Probe tool, the results are presented along with the results from the other automated probes. If the origin of the probe was a flight plan amendment or change in status of a preferred route, the information is displayed in a separate message to the controller on the same display.

4.3.1.3 Controller's Response

Since preferred route segments, when applicable, are required to be included in the flight plan, the controller must either include the applicable segment of an ATC-preferred route in the flight plan or retract the proposed amendment. Both of these options are available on the interactive display.

The decision of how to handle an interception with a high traffic density area is left to the controller, who may modify the planned route, coordinate with the involved controller, or defer resolution. The message from the Long Range Probe serves

only as notification to the controller of the high density area.

4.3.2 Dynamic Airspace Probe

4.3.2.1 Stimulus

The Dynamic Airspace Probe will alert the controller to situations in which an aircraft's trajectory is predicted to intercept a defined hazardous weather area. The alert is analogous to the alert for a conflict with a static special use airspace except that the look-ahead time used by the probe may be significantly shorter due to the volatile nature of weather areas and the associated difficulty in forecasting future patterns and positions of the areas. Whereas conflicts with static airspaces can be detected across an entire center, conflicts with dynamic airspaces may be reliably detected only across one or two sectors.

4.3.2.2 Information Displayed

Advisory and priority messages about predicted conflicts with a hazardous weather area will be displayed to the controller, perhaps on the Alert and Resolution logical display. The messages will contain information to identify the conflict, such as aircraft ID, location of predicted interception, and time of predicted interception. Additional information will be available on controller request and may be presented on the Planning Display. The additional information will include data that might be useful to the controller or pilot in determining how to avoid the weather area, such as location and extent of the weather area, type of weather, and rate and direction of movement of the area. A graphical display may be an effective way to portray this information.

As with conflicts involving static special use airspace, if the interception with a dynamic airspace is predicted to occur in the sector in which the aircraft is currently flying, a priority message is sent to the controller of that sector. The priority message conveys the imminence and severity of the situation and warns that the aircraft should take immediate action to avoid the encounter. If, however, the interception is predicted to occur in a sector other than the one in which the aircraft is currently flying, the controller currently in control of the aircraft will be informed of the situation via an advisory message. The rationale behind the advisory message for an encounter with dynamic airspace differs from that for an encounter with static airspace. Rather than signifying that he interception is relatively certain to occur but is not

time-critical to resolve, encounters with weather can not be predicted with certainty, but warrant attention since they can quickly develop into more serious situations. In this way they are similar to conflicts between aircraft. The advisory message indicates that immediate action is not required on the part of the controller, but that this is a situation of which the controller and the pilot may want to be aware for planning purposes.

4.3.2.3 Controller's Response

The primary use of the priority or advisory message is as an information source for informing the pilot of impending situations. In the current system, and likely in AERA 1.02, the controller is not required to guarantee separation of controlled aircraft from severe weather areas. Rather, the controller is directed to inform pilots of identified weather areas and, if requested, to assist the pilot in avoiding the areas. As described in Section 4.1.2, Dynamic Airspace Probe, the controller's lack of information is related to his limited responsibilities in dealing with severe weather. In AERA 1.02 the controller will be better able to assist the pilot in avoiding areas of weather because of the additional data available in the priority and advisory messages and on the associated displays.

4.3.3 Conflict-Free Metering

4.3.3.1 Stimulus

When an aircraft must be metered, as determined by the metering function, a conflict-free metering advisory is generated for display to the controller. The advisory is displayed to the controller a specified (system parameter) time before it must be issued to the pilot to allow the controller time to revise the advisory, if necessary, before it must be transmitted to the aircraft (see Section 4.3.3.3, Controller's Response).

4.3.3.2 Information Displayed

The metering advisory is displayed to the controller in the form of a message on the Metering Advisory List logical display, containing the information needed to issue a clearance to the pilot to execute the maneuver. Such information includes the aircraft to be metered, the type of maneuver and the specific parameters for the maneuver (speed, descent point, descent rate, radar vector heading, time in hold, etc.). The controller is also informed of the amount of delay to be

absorbed and the goal to be accomplished (the time the aircraft should cross the fix or boundary) so that, if need be, an alternative advisory can be formulated.

To help the controller plan ahead, some relevant metering information could be presented on the Flight Data Display. For aircraft to be metered, the amount of delay to be absorbed and the type of maneuver being planned by the metering function (metered descent, speed, hold, vector) may be included in the display. This data would be displayed before the metering advisory is given to the controller to allow the controller to plan ahead and integrate the metering tasks with other control tasks. This data would be updated as required.

4.3.3.3 Controller's Response

The controller's decision as to whether or not to implement a metering advisory will be based primarily on a mental check for potential conflicts that could not be detected by the automated probes (e.g., those with out-of-conformance aircraft, VFR aircraft, etc.). While the advisory proposes an effective way of metering the aircraft as far as the automated probes can determine, the controller may have additional relevant information and is free to accept or reject the advisory based on his own knowledge and expertise. The display of the advisory is timed to allow the controller sufficient time to check for potential conflicts and formulate an alternative clearance if necessary. However, the advisory is presented close enough to the implementation time to be able to take advantage of the latest estimate of delay required.

If the controller decides to accept the advisory, the controller transmits the new clearance containing the metering maneuver to the pilot, receives an acknowledgment, and indicates to the computer that the advisory has been accepted. The details of the flight plan amendment need not be entered, since they are already available through the metering function.

At this point, the aircraft's flight plan is amended to include the metering maneuver, and the aircraft's trajectory is remodeled as necessary to reflect the change. The remodeling triggers the FPCP and AP to be run on the new trajectory. Normally no new conflicts will be detected since the metering advisory was already tested for conflicts before it was displayed to the controller. However, if there was a delay between the time the advisory was issued and the time it was accepted, a change to another aircraft's trajectory may have resulted in a conflict which could not have been detected

previously. The controller resolves these new conflicts as any other conflicts are resolved. It is expected that in most cases no new conflicts will develop when the advisory is implemented.

If the controller decides to reject the computer-generated advisory (most likely because of conflicts with aircraft that are not considered by the probes), the metering function will provide, on controller request, additional advisories that will allow the aircraft to meet the metering goal in a conflict-free manner. If desired, the type of maneuver to be employed can be specified. To do this, the controller might request a list of the maneuvers that the metering function can consider, and select a particular maneuver from this list. Alternatively, the controller could enter a trial amendment which reflects the desired maneuver.

The metering function will attempt to absorb the required delay in a conflict-free manner with the specified maneuver. If the attempt is successful, the advisory will be presented to the controller, who may accept and implement it using the procedure described above.

If only part of the delay can be absorbed by the specified maneuver, the controller is informed of the amount of delay remaining and may accept and implement the advisory, thereby absorbing part of the delay. The remaining delay will be absorbed by subsequent maneuvers planned by the metering function.

If the specified maneuver is infeasible, due to traffic or insufficient time to effect the maneuver, the controller is so informed and must select another maneuver to meter the aircraft.

4.3.4 Controller Reminders

4.3.4.1 Stimulus

The controller is notified of impending planned altitude changes in the trajectory by controller reminder messages that are displayed at the planned start-of-transition point. The planned altitude changes can originate either through explicit controller action or through normal flight plan initiation.

The messages for certain planned altitude changes implicit in the flight plan may be inhibited in adaptation, so that the reminders are useful to the controller and not a nuisance. An example of such a situation is the normal descent route into a

major airport. Since the controller handles many aircraft along this route every hour, a reminder on each one telling when the aircraft is to descend may not be needed. In this case, the reminders for aircraft arriving at this airport might be inhibited. On the other hand, if an aircraft is planned to descend to an infrequently-used airport, a controller reminder at the top-of-descent point may be useful and would therefore be presented.

4.3.4.2 Information Displayed

Included in the reminder message, which is displayed on the Alert and Resolution logical display, are the details of the planned altitude change, such as the aircraft involved, the new altitude, and any restrictions incorporated in the plan. If the controller explicitly planned the altitude change, all of this information would have been entered at that time. If the altitude change was deduced from the flight plan, the data is extracted from the flight plan and pertinent Letters of Agreement and facility Standard Operating Procedures.

4.3.4.3 Controller's Response

At the time a reminder message is displayed, the controller has the option to either issue the altitude change as planned or alter the plan by either issuing a different clearance or leaving the aircraft's current clearance in effect.

Most likely, the controller will issue the altitude change as planned, in which case the controller transmits the clearance, receives an acknowledgment, and indicates to the computer that the plan has been implemented. The flight plan amendment need not be entered explicitly since the information is already included in the trajectory.

If the controller decides not to issue the clearance as planned, it will be necessary to update the aircraft's current plan, which had contained the planned action which triggered the reminder. Failure to make the update would result in the aircraft being out of conformance with its trajectory, in which case an out-of-conformance alert for the aircraft would be presented to the controller, warning of the situation that had developed. Exactly how the aircraft's trajectory would be modeled in this situation is currently an open issue. The options being considered include stopping the trajectory modeling since the controller's intent is unknown, or making some facilitating assumptions about intent and approximating a reasonable estimate of the trajectory.

5. AERA 2.01

AERA 2.01 is the first in a series of packages, known as AERA 2, to offer the controller assistance in resolving problems detected by the advanced automation functions. In this package, the assistance is in the form of general advisories, while subsequent packages will provide more detailed information on specific resolutions. The following enhancements are discussed below: General Resolution Advisories, Multiple-Step Metering, and other improvements. In addition, the functions introduced in AERA 1 are expected to undergo incremental improvement.

5.1 Enhancement Features

5.1.1 General Resolution Advisories

The purpose of the new resolution function in AERA 2.01 is to assist the controller in arriving at resolutions for those conflicts which justify resolution processing. Long-range conflicts with a lower probability of resulting in a separation violation may not be reasonable candidates for resolution. The criteria for distinguishing between resolution candidates and non-candidates is an issue requiring further discussion.

In AERA 2.01, the dynamic resolution of conflicts is applied only to aircraft-aircraft conflicts. Dynamic resolution of conflicts with volumes of airspace or weather areas is reserved until later steps.

For each candidate aircraft conflict detected by FPCP, the system will generate several general resolution advisories which indicate alternative types of maneuvers that would be effective in resolving the conflict situation. The particular parameters of a maneuver (e.g., specific speed, altitude, vector heading, etc.) are not provided by the system, but would be furnished by the controller should the advisory be accepted. Once an advisory has been accepted and the specific parameters identified, the Trajectory Estimation function determines the start-of-maneuver point.

For airspace conflicts detected by Airspace Probe, the system will produce resolution advisories which indicate the designated preferred routes or Severe Weather Avoidance Plan (SWAP) routes for avoiding the airspace. The controller, should he decide to implement one of these advisories, is responsible for directing the aircraft to and from the identified routes.

The eventual goal of the automation effort is to have automation functions recognize conflict situations and identify the best resolution strategy in terms of maximizing system safety, minimizing adverse impact on aircraft and, to the extent possible, on controller workload. In the AERA 2 packages (AERA 2.01, 2.02, 2.03), the Conflict Resolution Planning function is added to the automation system and is first apparent to the controller in the form of general resolution advisories in AERA 2.01. Improved conflict resolution aids that provide more detailed information to the controller on effective resolution strategies evolve from the general advisories function and are available to the controller in AERA 2.02 and AERA 2.03.

5.1.2 Multiple-Step Metering

In AERA 2.01, a multiple-step plan for metering aircraft is formulated and presented to the controller for approval before any of the steps are implemented. The controller may accept all or part of the metering plan as it is presented. The accepted plan is incorporated into the aircraft's trajectory, and the controller is notified via Controller Reminder messages when it is time to issue the clearances to the aircraft.

In previous versions of the Metering Planning function, though several maneuvers were implemented to absorb the entire delay, only one maneuver was presented to the controller at a time, and that one not until it was time to implement the maneuver. The maneuvers were incorporated into the trajectory only as the controller implemented them, and since each maneuver absorbed only part of the delay, the trajectory was not completely current with the known metering plan while there was still delay to be absorbed.

The principal benefit of the multiple-step metering plan is expected to be that the controller can accept the whole plan at once, thereby allowing the trajectory to be complete and current. Additionally, the controller can be aware of upcoming maneuvers that the aircraft will make and can formulate control plans accordingly.

5.1.3 Other Enhancements

The use and capability of data link will be greatly expanded in AERA 2.01. The primary capability that affects the operation of the ATC system is that non-control messages (requests for weather information, terminal configurations, etc.) can be

handled without controller intervention. Requests for information are downlinked directly to the ground-based computer and are received, processed, and responded to without any action necessary on the part of the controller. The requested information is relayed to the aircraft via data link. This automation frees the controller to concentrate on actions which require his skill and judgment.

Another enhancement in AERA 2.01 is that the Controller Reminder messages are expanded to cover planned actions for conflict resolution. The Conflict Resolution Planning function may generate an advisory that contains maneuvers that are to be implemented at some specified time in the future. If the controller accepts the advisory, the maneuvers are automatically incorporated into the aircraft's trajectory, and the Controller Reminder messages will be displayed at the appropriate time to notify the controller when the planned maneuvers are to be implemented. The ability to specify planned actions for conflict resolution strategies helps to maintain the integrity of aircraft trajectories.

5.2 Functional Description

Figure 5-1 illustrates the primary internal interfaces between these AERA 2.01 components. A more detailed description of the interfaces (both external and internal), as well as a description of the relative processing sequence of the components is provided in the following paragraphs.

5.2.1 Trajectory Estimation

As in AERA 1.02, the purpose of Trajectory Estimation has not changed from previous steps, but an important enhancement has been added: the ability to model goal-oriented Resolution Planned Actions. This feature allows the Solutions Planning component to specify a particular type of maneuver to resolve a conflict, using one of the following Planned Actions:

- Resolution vector
- Altitude for resolution
- Hold (available in AERA 1.01)
- Speed for resolution

5.2.1.1 Execution Stimuli

The only change to the list of events which trigger the activation of Trajectory Estimation is the addition of the request from the Conflict Resolution Planning function (of the

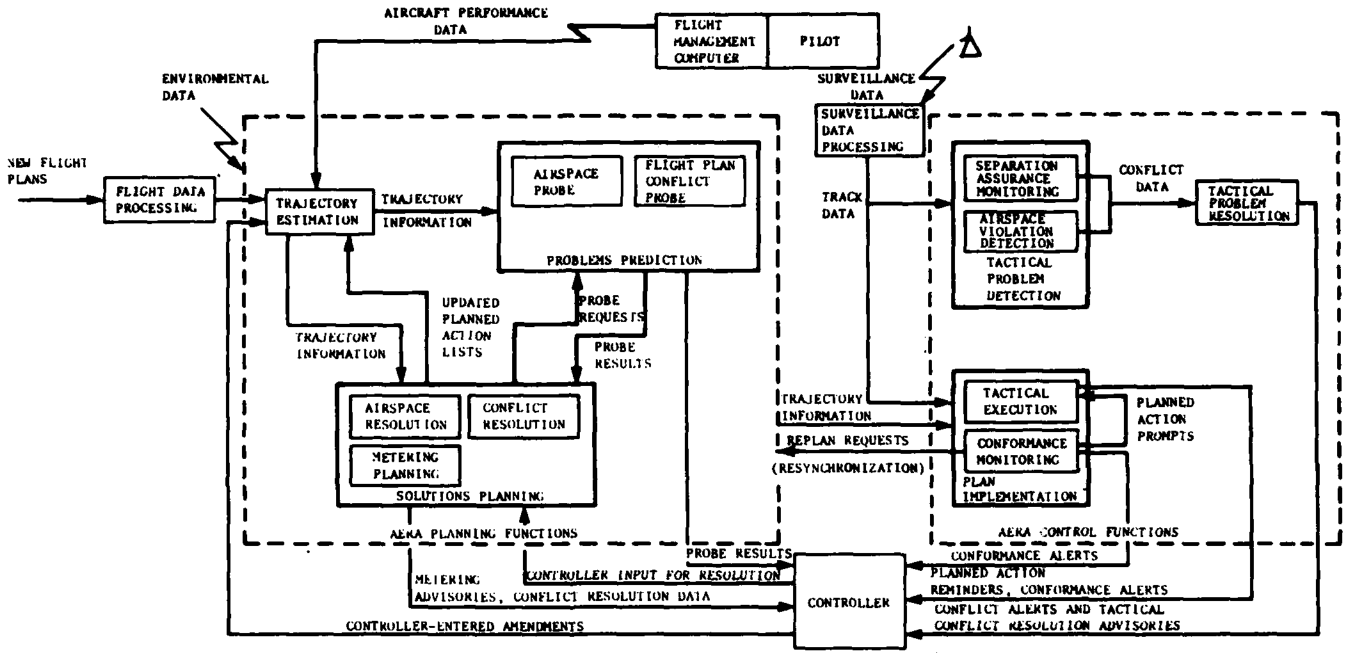

FIGURE 5-1
FUNCTIONAL COMPONENTS – AERA 2.01

Solutions Planning component) to incorporate a Resolution Planned Action. All other stimuli remain the same: Trajectory Estimation is activated to construct a new trajectory for a newly received flight plan or to update an existing plan.

5.2.1.2 Interfaces

No new external interfaces are added in AERA 2.01, and the only new internal interface is the addition of the request from Conflict Resolution Planning to incorporate the Resolution Planned Actions.

5.2.2 Problems Prediction

In AERA 2.01, no functional changes are made to the elements of Problems Prediction. Sector Workload Probe, Long Range Probe, Airspace Probe, Flight Plan Conflict Probe, and Metering Prediction each have the same functional capabilities and basic processing sequences as described for AERA 1.02.

5.2.2.1 *Execution Stimuli*

With the exception of Sector Workload Probe, which is driven by requests from a supervisor, the functions in Problems Prediction are activated whenever a new trajectory is constructed or an existing one is modified. That does not change in AERA 2.01, although there are new reasons for the modification of trajectories: planned actions generated by the Conflict Resolution Planning function will be incorporated in the trajectories, and the Problems Prediction functions will be initiated to probe for conflicts.

5.2.2.2 Interfaces

There are no changes in external interfaces with the Problems Prediction functions, and the only difference in internal interfaces is the feedback of conflict information to the Conflict Resolution Planning function.

5.2.3 Solutions Planning

In AERA 2.01, in addition to maintaining Metering Planning, the strategic Solutions Planning component gains a very important enhancement in the form of the Conflict Resolution Planning function. It should be stressed that this function is a strategic function, not to be confused with the resolution capability in the Tactical Problem Resolution component.

5.2.3.1 Conflict Resolution Planning

The resolution of aircraft-aircraft conflicts in AERA 2.01 is a rudimentary version of dynamic conflict resolution, in that an interactive conversation with the controller is maintained in order to obtain specific parameters of the resolution. (In later AERA steps, the Conflict Resolution Planning function itself determines the parameters of the resolution maneuvers.)

The first processing step that Conflict Resolution Planning takes is to decide which conflicts are candidates for resolution. Having decided upon a conflict to resolve, the function selects (based upon a predetermined set of rules) the type of Planned Action to be used in avoiding the conflict. This is then displayed to the controller, who specifies the parameters of the planned action. (For example, if the selected planned action were a "speed change for resolution," the controller would decide whether to increase or decrease speed, and what the target speed should be.) Upon receipt of the parameters, Conflict Resolution Planning submits the new planned action and the existing trajectory to the Trajectory Estimation process for remodeling. The new trajectory is then probed for conflicts and the results returned to the resolution process. These results are then displayed to the controller as a trial plan.

As with any trial plan, the controller may approve or discard the plan. If the plan is approved, it is stored as the current plan, and when the appropriate time is reached, a reminder will be issued to the controller, specifying the action to be taken. If the plan is not approved, the controller has the option of requesting that the Conflict Resolution Planning function try another solution to the same conflict, or may compose his own resolution. In the latter case, the Conflict Resolution Planning function is not involved. However, if the controller requests that a different resolution be generated by the system, the Conflict Resolution Planning logic must "remember" which solution was already tried and discarded, so as not to select the same resolution again. From that point on, the processing is the same as that already described.

5.2.3.2 Metering Planning

In AERA 2.01, Metering Planning calculates the entire metering plan for an aircraft at one time, rather than planning one advisory at a time and waiting for controller approval, as in the previous step. After the Metering Prediction function has determined the amount of delay to be absorbed, Metering Planning

generates an initial (trial) plan which distributes the delay (which planned actions to use where, and how much delay each should absorb). After generating the initial parameters for each planned action, the entire plan is given to Trajectory Estimation to model, and the resulting trajectory is passed to Problems Prediction for probing. The results of the probes are returned to Metering Planning, which may then have to refine the plan and repeat the modeling and probing process until a satisfactory plan is achieved. The entire plan is then presented to the controller for approval, and upon receipt of approval, the trial plan is made current. (If the controller does not wish to approve the plan, he may alter it or construct his own plan, as described in the AERA 2.01 operational description in Section 5.3.2, Multiple-Step Metering.)

5.2.3.3 Execution Stimuli

The Conflict Resolution Planning function is activated following a conflict probe which resulted in the detection of one or more conflicts. Following the display to the controller of a candidate planned action, the function waits for a response, and when the controller does respond, Conflict Resolution Planning is again activated to complete processing of the resolution. Conflict Resolution Planning might also be invoked by the controller to generate a resolution for a potential conflict detected by the Trial Plan Probe.

The stimuli for activation of Metering Planning are the same as in the previous step: receipt of a new flight plan or amendment of an existing plan for an aircraft in a metered flow, modification of the metering goals, or resynchronization of a metered plan.

5.2.3.4 External Interfaces

The results of the initial phase of the resolution processing (selection of the resolution maneuver) are presented to the controller, and the controller response is returned to Conflict Resolution Planning. In addition, the entire metering plan for an aircraft is displayed to the controller, and the controller response returned to Metering Planning.

5.2.3.5 Internal Interfaces

The Conflict Resolution Planning function issues requests to the Trajectory Estimation process to incorporate Resolution Planned Actions, and it receives the results of the conflict

probes on that new trajectory. The internal interfaces of Metering Planning are unchanged from the previous step.

5.2.4 Plan Implementation

The introduction of the planning enhancements in this step does not affect the Conformance Monitoring function. The execution stimuli, external and internal interfaces remain unchanged from the previous step.

The Tactical Execution function is not significantly affected by the planning enhancements; its processing continues as in AERA 1.02, although goal-oriented Resolution Planned Actions as well as Altitude Planned Actions are now modeled and processed by TEX. (Conformance Monitoring is still performed only for altitude Planned Actions.)

There are no changes for Tactical Execution in the execution stimuli or external interfaces from the previous step.

5.2.5 Tactical Problem Detection

The Separation Assurance Monitoring and Airspace Violation Detection functions are unchanged by any of the new features of AERA 2.01.

5.3 Operational Description

5.3.1 General Resolution Advisories

5.3.1.1 Stimulus

General Resolution Advisories are generated for conflict situations that have been identified by the automated probes as candidates for resolution and displayed to the controller.

5.3.1.2 Information Displayed

General Resolution Advisories are displayed on the logical Alert and Resolution display along with the message notifying the controller of the conflict. For aircraft conflicts, the advisory identifies a type of maneuver that would be effective in resolving the conflict. Examples of advisories might be "climb aircraft A" or "turn aircraft A behind aircraft B." The specifics of each maneuver (e.g., altitude, speed, heading) are not provided by the system in the advisory but are left for the controller to specify.

For conflicts with special use airspace, the advisories identify the preferred routes or SWAP routes for avoiding the airspace. Maneuvers required for the aircraft to reach the preferred or SWAP routes are not provided in the advisory, but are left for the controller to specify.

5.3.1.3 Controller's Response

When a conflict is detected, the controller's responsibility is to devise a resolution to the conflict, using either one of the strategies suggested in the advisories or one of his own invention.

Since an advisory presents only a type of maneuver without the specific parameters required to amend the flight plan or issue a clearance, if the controller decides to consider the maneuver proposed in an advisory, he must specify the parameters to be used. He does this using his own expertise and knowledge of the current traffic situation. To facilitate the entry of the parameters, the computer automatically presents an appropriate display once the controller indicates which advisory he wants to consider. Without having to specify the entire maneuver, the controller selects the particular parameters from the display. If a start-of-maneuver point can be identified by Trajectory Estimation such that the conflict would be resolved by the maneuver, a Trial Plan Probe is run automatically to ascertain whether any additional conflicts would be created. The results of the Trial Plan Probe are presented to the controller. If the controller accepts the advisory, the maneuver is inserted into the aircraft's trajectory, and Controller Reminder messages will be generated to notify the controller when to issue the clearance to the aircraft.

If the advisories are unacceptable to the controller he may enter his own resolution. In this case the entire maneuver must be entered--the aircraft ID, the type of maneuver, and the specific parameters. Since the resolution is still goal-oriented, the optimal start-of-maneuver point will be determined by Trajectory Estimation. If the controller gives final approval to the maneuver, a Controller Reminder message will be displayed at the appropriate time.

5.3.2 Multiple-Step Metering

5.3.2.1 Stimulus

As in previous automation packages, Metering Planning determines which aircraft must be metered, identifies maneuvers that

will absorb the required amount of delay, and displays them to the controller in the form of metering advisories. In AERA 2.01, the entire metering plan, which will typically consist of multiple steps, is generated at one time and presented to the controller for approval. After the controller approves the plan, Controller Reminder messages are sent when it is time to implement each step of the plan.

5.3.2.2 Information Displayed

The display of the multiple-step metering plan contains the aircraft to be metered, the meter fix or boundary, the meter goal, and, for all steps, the specific maneuvers and the amounts of delay to be absorbed.

5.3.2.3 Controller's Response

The controller may approve all or part of a metering plan presented by Metering Planning. This is done through the interactive display on which there will be a specific option for approval of metering plans. If the plan is accepted as a whole, it is immediately incorporated into the aircraft's trajectory, and the controller will receive Controller Reminder messages at the appropriate times for implementation of the individual steps.

If the controller decides to accept only part of the metering plan, the controller specifies the steps to accept, if any. The computer will display the amount of unabsorbed delay. The controller may request an additional advisory suggesting a different maneuver to absorb the remaining delay, or may develop his own plan. Trajectory Estimation determines start-of-maneuver points for all maneuvers, and if the controller accepts any part of the plan, the trajectory is updated accordingly.

6. AERA 2.02

AERA 2.02, the second stage in AERA 2, reflects enhancements to the computer-aided, problem-resolution function introduced in AERA 2.01. The following sections discuss Specific Resolution Advisories, Separation Assurance Monitoring, transmission of clearances via datalink, and several other enhancements.

6.1 Enhancement Features

6.1.1 Specific Resolution Advisories

From experience gained in previous automation packages, the Conflict Resolution Planning function in AERA 2.02 is capable of proposing effective specific resolutions to detected conflict situations. The resolution advisories contain all of the specific parameters needed to issue the clearance and amend the flight plan. With the advent of this capability, the controller's role in the conflict resolution process can be reduced to final arbiter, with the tasks of generating effective specific resolutions and transmitting the associated clearances to the pilot via datalink performed by automation functions (see Section 6.1.2, Uplink of Approved Clearances).

In AERA 2.02, Conflict Resolution Planning is designed to suggest several specific resolution strategies to the controller on the assumption that the controller is best able to select the optimal strategy. By AERA 2.03, with the experience gained in this automation package, the automated resolution generator will be able to independently select the best strategy for most conflict situations, thus freeing the controller to concentrate on unusual circumstances in which his skills are required.

6.1.2 Uplink of Approved Clearances

In AERA 2.02, the expanded data link capability can be used to automate a significant activity previously performed by the controller, transmitting clearances to aircraft. Clearances that have been generated by one of the automation functions, such as metering plans, conflict resolution maneuvers, control actions implied by the flight plan, or planned actions that have been input by the controller, can be automatically uplinked to appropriately equipped aircraft after they are approved by the controller. The aircraft's trajectory is updated after the pilot acknowledges reception of the clearance, which is done via datalink or voice.

The automatic handling of clearances is a major step in the transition to a fully-automated ATC system. The controller's role progresses toward that of expert overseer, in which he approves decisions, maintains awareness of actions being taken, but relinquishes routine tasks that are more easily automated.

6.1.3 Separation Assurance Monitoring

The Conflict Alert function, which previously predicted conflicts between radar tracks assuming there was no change in direction or speed, is expanded in AERA 2.02 to consider flight plan intent as well. This enhanced function is termed Separation Assurance Monitoring (SAM). Though for safety reasons there is always a need for an independent conflict-detection capability based solely on radar target data, the nuisance value of the false consideration of alerts generated by this process is expected to be reduced by the aircraft trajectories which represent the current control plan for the aircraft. The Separation Assurance Monitoring function uses estimates of future aircraft position made with and without knowledge of aircraft intent to categorize situations in which separation may be lost.

An important difference between this new prediction method and the strategic Flight Plan Conflict Probe is that SAM uses the aircraft's current, actual position as the starting point of the prediction. This short-term prediction is intended to detect near term violation of separation criteria that will occur if the aircraft follow their expected routes.

Predictions of violations made by the two methods produce different alerts to the controller. Since the trajectory-aided estimate of aircraft position reflects the most current knowledge of the intent of the aircraft, violations predicted using this method have a high probability of occurring and are therefore displayed to the controller in a high-level, attention-getting alert. Violations predicted on the basis of radar track projections are false alarms more often than is desirable, but their detection provides a useful backup warning system and is displayed in low-level alerts. The two levels of alerts warn the controller of all possible problems detected by the function in a manner that helps the controller evaluate the severity of the situation.

6.1.4 Other Enhancements

The Mmetering Planning function will have been tested to such an extent by the time AERA 2.02 is implemented that there will

be a high degree of confidence that the metering plan proposed by the function to accomplish the metering goal will be acceptable. This confidence allows the plan to be incorporated into the trajectory as soon as it is generated rather than after controller approval is obtained. Early inclusion of the metering plan, which is the best estimate of the true flight path of the aircraft, allows the trajectory to remain current and complete.

The capability to handle Controller Reminder messages is expanded in AERA 2.02 to allow the controller to plan any type of maneuver for future implementation. At the time the maneuver is scheduled to be executed, the controller is notified via a reminder message.

6.2 Functional Description

The relationships and interfaces between the AERA-related components for AERA 2.02 are illustrated in Figure 6-1 and described in the following paragraphs.

6.2.1 Trajectory Estimation

No changes or enhancements are made in AERA 2.02 to the Trajectory Estimation component. Its execution stimuli also remain the same: It is activated whenever a new trajectory must be constructed or an existing one modified. Its calling sequences remain unchanged, although new uses of the trajectories appear in this step (for example, the use of trajectories in the Separation Assurance Monitoring function). The new uses do not actually impact the internal processing of this component, and so will be discussed in the paragraphs describing the using components.

6.2.2 Problems Prediction

The only change to this component is the upgrading of the Long Range Probe function. The enhancements to this function may take the form of automation of the tasks of the supervisor (as described in the section on AERA 1.02) pertaining to the specification of high density areas and ATC-preferred routes. Data on expected and historical traffic flows will be evaluated by the automation in order to inform the controller of any anticipated control problems beyond the range of the Flight Plan Conflict Probe.

The execution stimuli would remain unchanged, as would internal interfaces. External interfaces may be modified to incorporate

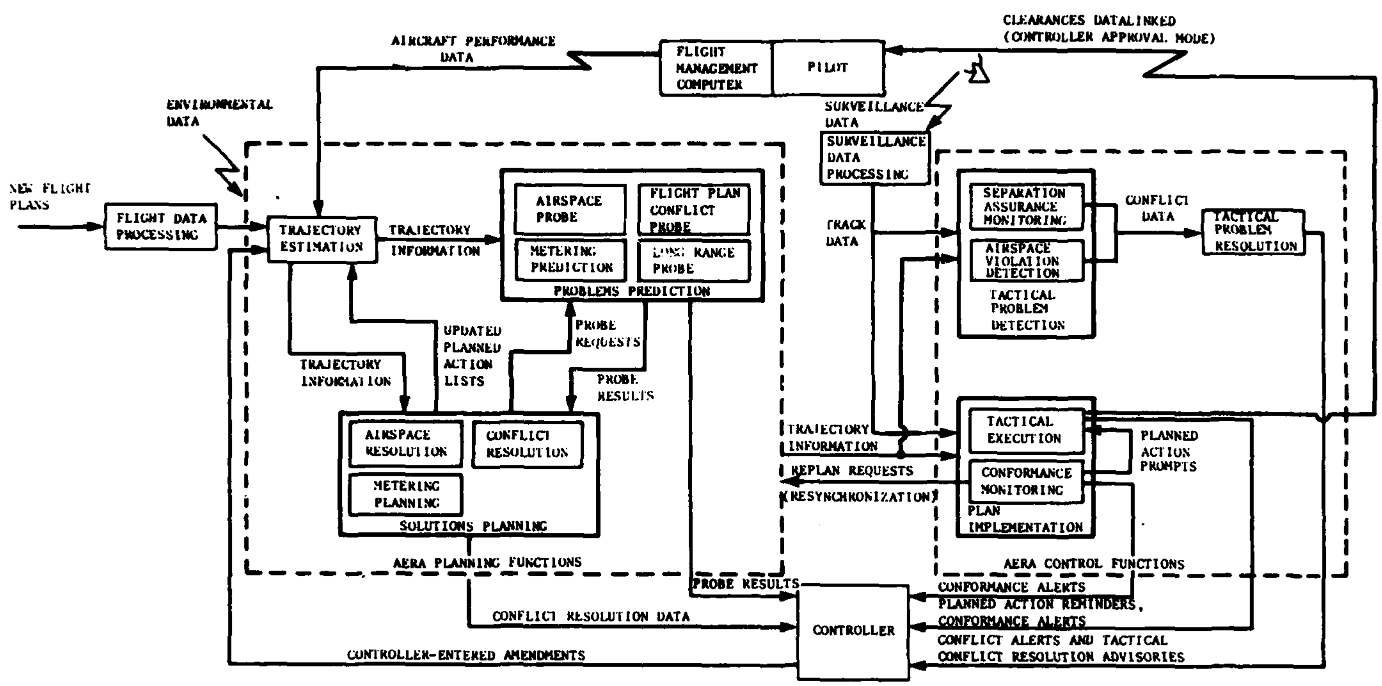

FIGURE 6-1
FUNCTIONAL COMPONENTS – AERA 2.02

possible definition (in the system data base) of traffic flow patterns.

No changes in the other functions of the Problems Prediction component occur in this step.

6.2.3 Solutions Planning

In AERA 2.02, the two constituents of the Solutions Planning component remain the same as in the previous step: Conflict Resolution Planning and Metering Planning.

6.2.3.1 Conflict Resolution Planning

The first processing step, as in AERA 2.01, is to determine which of the conflicts in the encounter data base require the attention of the Conflict Resolution Planning function. Once a conflict has been selected, a maneuver category and an initial selection of the parameters (or constraints) is performed, based upon a prioritized set of rules. The end result is a planned action description.

This description of the planned action is then passed to the Trajectory Estimation function, along with the existing horizontal route, and the new maneuver is incorporated as a trial plan. The resulting trajectory is subjected to the probe functions of the Problems Prediction component, and the results are returned to Conflict Resolution Planning.

The probe results are examined to determine if the generated planned action accomplished a successful resolution. The criteria for success include the following considerations:

- Was the conflict under consideration resolved?

- In removing the above-mentioned conflict, were new ones created? If so, are the new ones "acceptable" for the purposes of this resolution? (A new, less probable conflict predicted to occur in thirty minutes may be an acceptable trade-off for resolution of a closer, more probable conflict.)

If problems are detected with that particular resolution, the Conflict Resolution Planning function will try another resolution. This new resolution may be based upon a new type of maneuver altogether, or it may be the same maneuver with different constraints. For example, a Resolution Vector

planned action employing a left turn may be replaced with the same planned action with a right turn. Conflict Resolution Planning must keep track of those planned actions (and their parameters) which have previously been tried, so as not to repeat resolutions which were unsuccessful.

Since multiple resolutions are presented to the controller in this step, the above processing is repeated until the required number of successful advisories have been generated (or, if the required number of successful advisories cannot be found, until all reasonable combinations have been attempted).

If one of the advisories is accepted by the controller, the plan is made current and becomes the trajectory used to probe against other aircraft. If the controller decides to specify a new advisory, the Conflict Resolution Planning function is not involved, since the controller is then performing the planning function himself. The other planning tools such as Trial Plan Probe will be available, however.

6.2.3.2 Metering Planning

The basic change to the automatic metering process is that the Metering Planned Actions are incorporated into the current plan when they are generated, rather than only after controller approval of the plan. This has no effect on the generation of the metering plan. The incorporated metering plan is indicated to the controller as separate information, as a message or on the trajectory display for that aircraft.

6.2.3.3 Execution Stimuli

As in AERA 2.01, the Conflict Resolution Planning function is activated following the probes of the Problems Prediction component, if necessary (i.e., if any conflicts were detected by the probes).

There is no change in the activation stimuli for Metering Planning.

6.2.3.4 Interfaces

The internal interfaces of Conflict Resolution Planning remain the same, and the external interface with the controller changes slightly, in that the planning interaction of AERA 2.01 is removed.

Similarly, the internal interfaces of Metering Planning remain unchanged, but the external interface with the controller (for approval of the metering plan) is deleted. A message or other method to inform the controller about the metering plan is added.

6.2.4 Plan Implementation

The Conformance Monitoring function does not have any enhancements or modifications, in AERA 2.02; its execution stimuli and interfaces, both internal and external, remain unchanged from AERA 2.01.

The Tactical Execution function monitors for adherence to the issued clearance and the intent of the planned action, for all types of planned actions. In addition, clearances approved by the controller are datalinked directly to the aircraft when appropriate.

6.2.4.1 Execution Stimuli

No change in execution stimuli occurs for this step: Tactical Execution is still notified by the Conformance Monitoring function when it is time to monitor a planned action sequence, and it is still activated when new track data is available for an aircraft being monitored.

6.2.4.2 Interfaces

An important external interface new to this step is the addition of the datalink to the aircraft. Internal interfaces remain the same as previous steps.

6.2.5 Tactical Problem Detection

This functional area consists of Separation Assurance Monitor and Airspace Violation Detection, enhanced versions of Conflict Alert and MSAW respectively.

As described above, an important change in the Tactical Problem Detection philosophy appears in AERA 2.02. In addition to the current Conflict Alert and MSAW (where the present position of the aircraft is projected forward with assumed constant velocity), a second type of prediction is made. The new prediction is based upon the current position of the aircraft and any expected near term maneuvers.

6.2.5.1 Execution Stimuli

There is no change in the stimulus activating Tactical Problem Detection--the component is activated by the receipt of new tracking data, just as in the AERA 2.01 version.

6.2.5.2 Interfaces

The only change to the external interfaces is the presentation to the controller of alert messages (and associated resolution advisories) resulting from trajectory-aided predictions.

The change in the internal interfaces consists of the use of the strategic trajectories in detecting imminent conflicts with aircraft or designated airspace areas.

6.3 Operational Description

6.3.1 Specific Resolution Advisories

6.3.1.1 Stimulus

Specific resolution advisories are generated for all conflict situations detected by the automated probes and displayed to the controller, as were the general resolution advisories in AERA 2.01.

6.3.1.2 Information Displayed

Specific resolution advisories, which are displayed on the Alert and Resolution logical display along with the notification of the conflict, contain all the information needed to transmit the clearance to the aircraft and amend the flight plan. This includes the aircraft ID, the type of maneuver (altitude change, speed change, hold, radar vector, etc.), a d the specific parameters relevant to the particular maneuver being implemented. A limited number of advisories (perhaps three or four) are presented to the controller. If the controller accepts one of the advisories, this information can be reformatted into a clearance and transmitted directly to the aircraft via datalink.

6.3.1.3 Controller's Response

As with other advisories, the controller evaluates the specific resolution advisories presented and decides, based on his expertise and knowledge of the traffic situation, which, if any, of the advisories to accept. An option on the interactive

display allows the controller to accept an advisory exactly as it was presented. If the aircraft is adequately equipped to receive data link messages, another option permits the controller to have the associated clearance uplinked directly to the aircraft. In the optimal situation, the controller need only select these two options to implement a resolution strategy.

If the controller is mostly satisfied with one of the resolution strategies but wants to modify the specific parameters, the capability to edit the displayed resolution will be available. For instance, the controller may agree that an altitude change is the best approach for resolving the conflict, but may disagree with the specific altitude suggested, or may want to issue the change to the other aircraft involved. To facilitate the modification process, a limited number of valid entries for the field could be presented to the controller, who might select one of the entries or enter a different value via the keyboard. After the controller has modified the advisory so that it is acceptable, the advisory may be implemented as described above.

If the advisories presented are unsatisfactory to the controller, a different maneuver and specific parameters may be specified by selecting options on the interactive display. A resolution specified in this way is still goal-oriented, and the optimal placement of the maneuver will be determined by the Trajectory Estimation function. If an effective resolution can be generated using the selected maneuver, an advisory containing the resolution will be displayed, and the controller can then implement it.

6.3.2 Uplink of Approved Clearances

6.3.2.1 Stimulus

When the controller wants to issue a clearance, regardless of whether it has been strategically or tactically planned, the clearance can be uplinked to the aircraft if the aircraft is appropriately equipped.

6.3.2.2 Information Displayed

Advisory messages that suggest maneuvers for aircraft contain, besides a specific maneuver, an indication of whether or not the aircraft has the equipment required to receive a data link clearance. There is also an indication of equipment status

within the aircraft data for each flight. On the interactive display, there is an option which can be selected when the aircraft has the appropriate equipment, which will transmit the clearance via data link. The option is disabled if the aircraft cannot receive a data link message.

6.3.2.3 Controller's Response

The controller determines whether datalink can be used by checking the equipment indicators. The datalink option may be selected if it is enabled, which will cause the clearance to be transmitted to the aircraft. So that the controller can monitor the process, an indication that the clearance has been transmitted is displayed. The system waits for the pilot to acknowledge the clearance before incorporating the amendment into the trajectory. When the acknowledgment has been received, the controller is notified. A separate verbal acknowledgment from the pilot may also be required.

6.3.3 Separation Assurance Monitoring

6.3.3.1 Stimulus

As in previous versions, a Separation Assurance alert is displayed to the controller when the predicted positions of two aircraft will violate separation criteria within a specified amount of time (usually approximately two minutes). Predictions of violations are made by two methods: using track data only, and using trajectories supplemented by radar position reports. The two methods generate different alerts to the controller.

6.3.3.2 Information Displayed

For situations in which the trajectory-aided position estimates are in conflict, the alert may be similar to the current Conflict Alert in which the data blocks flash. The controller can display track vector lines to help visualize the location and configuration of the predicted violation.

The low-level alert for radar-based predictions is displayed in a more subtle manner. One possible format for the alert would be for the projected flight paths to be displayed on the PVD, perhaps in a distinguishing color, showing the location of the predicted violation. The projections would be a non-distracting yet identifiable alert to the controller of a potential problem.

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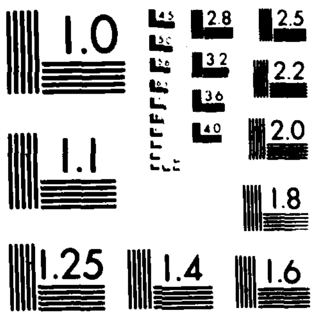

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6.3.3.3 Controller's Response

As in today's system, the controller would be required to evaluate all Separation Assurance situations to determine if a conflict truly exists and what the optimal course of action is. If the controller decides the situation will not develop into a separation violation, the alert may be turned off, in which case either the data blocks will stop flashing or the projections will disappear. If the situation warrants resolution, the controller may implement the maneuver proposed in the Conflict Resolution Advisory associated with the alert, or may implement his own strategy for resolution.

7. AERA 2.03

AERA 2.03 is the final transition package before complete automation. All functions operate as if they were automated except that controller approval is required before the machine-generated resolutions are implemented. Enhancements in the following areas are discussed below: single global resolution advisories, resolutions for deviations from trajectories, and clearances datalinked in veto mode.

7.1 Enhancement Features

7.1.1 Single Global Resolution Advisories

In AERA 2.03, conflict resolution strategies are generated by a "super planner" that has knowledge of the global traffic picture, including the goals of such functions as Metering Planning and Conflict Resolution Planning. This perspective allows the planner to design resolution strategies that address multiple goals simultaneously. The single optimal resolution strategy for a particular situation is selected and presented for controller approval, based on experience gained from the multiple resolution advisories generated in AERA 2.02. There is a high degree of confidence that the controller, who must still approve all resolutions before they are implemented, will approve the proposed strategy. To help the controller understand the reasoning why a particular strategy was selected, the rationale used by the automation function is available to the controller on request.

The integration of several high-level control functions that permits the display of a single, goal-oriented, global resolution strategy is one of the last major steps on the road to full automation. In previous packages, individual functions were automated, but the controller was required to integrate the results of the various functions in order to develop a cohesive control plan for the sector. Some of the individual functions were designed to work with other functions (e.g., conflict-free metering), but the functions were not capable of resolving more than one goal simultaneously, even concurrent problems of the same type (e.g., an aircraft with more than one conflict). In this package, the automation functions are integrated so that the system acts as if it were fully automated, except that controller approval is still required before action can be taken. Removing the controller from the implementation loop will be the final step to full automation in AERA 3.

7.1.2 Resolutions for Deviations from Trajectories

A new aid is introduced in AERA 2.03 that provides the controller with machine-generated resolutions to detected deviations from the aircraft's trajectory. Whereas in previous packages the controller was informed of trajectory deviations but was required to generate his own resolutions, the new aid supplies resolutions that allow the aircraft to meet its planning objectives (metering, conflict resolution, etc.) in the most efficient manner from its present position. The automation system considers planning objectives, neighboring aircraft trajectories, present position of the aircraft, and the global control plan to determine the optimal strategy.

When an aircraft deviates from its trajectory, for instance due to a pilot-initiated deviation around a severe weather area, it is an important and sometimes difficult task to reunite the aircraft's flight path with the computer-generated trajectory. Since the trajectory represents the current plan for how the aircraft will meet all of its planning objectives, deviations from the trajectory may imply that some objectives will not be met, which can have far-reaching consequences in the control plan of the sector. A direct return to the trajectory may not always be the optimal solution since the aircraft may not be able to maneuver back to the trajectory (e.g., if it is already in a maneuver), or the aircraft's timing may be off such that planning objectives, especially metering, may be missed, or a direct route to the next fix may be more efficient. In such instances, alternative trajectories must be generated and possibly the objectives redefined. The integration of the high-level control functions in AERA 2.03, as described in Section 7.1.1, makes the automation system well-equipped to do all the necessary calculations.

7.1.3 Clearance Datalinked in Veto Mode

In AERA 2.03, the use of datalink is expanded so that planned clearances are automatically datalinked to the aircraft unless the controller explicitly inhibits their transmission. This capability applies to all planned clearances: conflict resolutions, controller planned actions, flight plan-implied planned actions, metering maneuvers, outbound handoffs, etc. At the time a clearance is to be implemented, a message is displayed to the controller that is similar to the reminder messages of previous packages. The message notifies the controller that unless it is vetoed, the clearance contained in the message will be datalinked to the aircraft at the appropriate time. The controller need take no action to have

the clearance implemented as planned. Only under exceptional circumstances will the controller's intervention be required, in which case he can expedite, reject, or hold any planned clearance (see Section 7.3.3, Datalink Clearances for detailed descriptions of these options).

The automatic datalink of clearances with controller veto power is only one step away from the complete automation of the clearance implementation process that will exist in AERA 3. In AERA 2.03, the opportunity for controller intervention is built into the implementation process. Though it need not impede implementation if everything is to go as planned (in which case the controller makes no overt response to the notification message), the controller is provided the opportunity to intercede if the situation demands. In AERA 3, clearance delivery (as well as other control functions) is performed entirely by the automation system, with the controller monitoring activities at his discretion.

7.2 Functional Description

The relationships and interfaces between the AERA-related components for AERA 2.03 are illustrated in Figure 7-1 and described in the following paragraphs.

7.2.1 Trajectory Estimation

No new changes occur in this component--its functional capabilities, execution stimuli and interfaces remain the same as in the previous step.

7.2.2 Problems Prediction

None of the functions in this component has any modifications or enhancements for this step. All interfaces and execution stimuli remain the same as in AERA 2.02.

7.2.3 Solutions Planning

7.2.3.1 Conflict Resolution Planning

In AERA 2.03, the resolution planning gains an important enhancement, that of global perspective of conflict resolution. This broadening of scope of the Conflict Resolution Planning function is an attempt to give the automated elements the "big picture" that the human controller has. Instead of terminating resolution planning with the first successful resolution, the new resolution function evaluates several

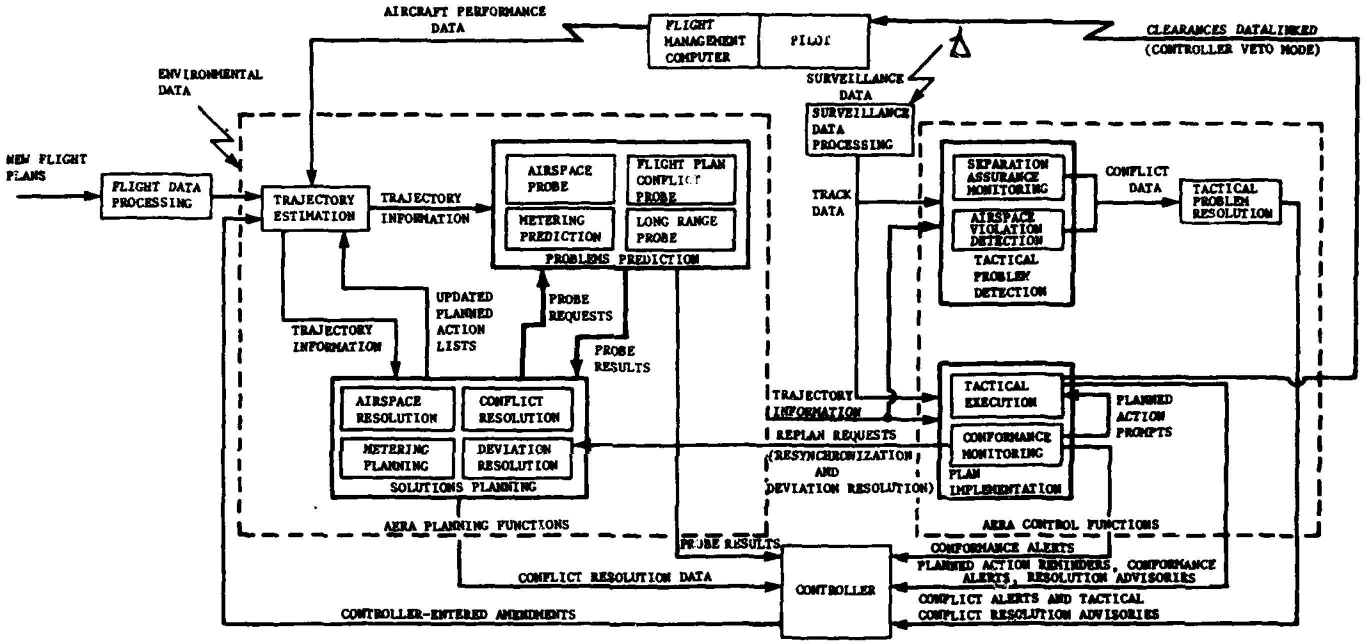

FIGURE 7-1
FUNCTIONAL COMPONENTS – AERA 2.03

successful solutions and makes a determination of the "best" alternative resolution, one which will optimize the traffic situation (and possibly, as a side benefit, reduce controller workload) for a given area, probably the Planning Region. The Conflict Resolution Planning function will also combine or utilize some of the planning elements of the Metering Planning function. Perhaps the easiest way of describing the scope of this improved function is by providing a comparison with previous Solutions Planning component functions, and by illustrating the new capabilities with an example.

In the previous Conflict Resolution Planning function, a set of pre-defined rules was used to determine which type of maneuver to use, and what parameter values to initially try. If that maneuver was successful, there was no reason to explore further resolutions, other than to provide the controller with multiple successful solutions from which to select. If an aircraft had several conflicts along its trajectory, each was considered and resolved individually. Since metering goals were not considered directly as part of the resolution strategy, it was possible that a maneuver which resolved the conflict may have also interfered with the metering plan. The controller had to consider that fact when evaluating the resolutions presented.

In AERA 2.03, the Conflict Resolution Planning function examines all conflicts detected for a given aircraft, not just the first one. A number of resolutions are generated for the first conflict, and the effect of each resolution on the other conflicts of that aircraft and on the aircraft's metering goals are then evaluated. The solution which has the most desirable overall effect on the aircraft's plan is then selected for possible incorporation into the plan. In order to decide which aircraft in a conflict should be the "burdened" aircraft (i.e., the one which is given the maneuver), it may be necessary for the resolution function to examine candidate resolutions for both aircraft involved in the conflict, and choose the maneuver which has the most beneficial effect on the overall traffic situation.

A simple example of the use of the Conflict Resolution Planning function is illustrated in Figure 7-2. The diagram shows aircraft A proceeding eastward and involved in two conflicts, one with aircraft B and another, further downstream, with aircraft C. If the conflicts are examined individually, it may appear more beneficial to move B in order to solve the first conflict; however, this would require another maneuver later by either A or C to resolve the second conflict. By moving aircraft A to a different altitude to resolve the first conflict,

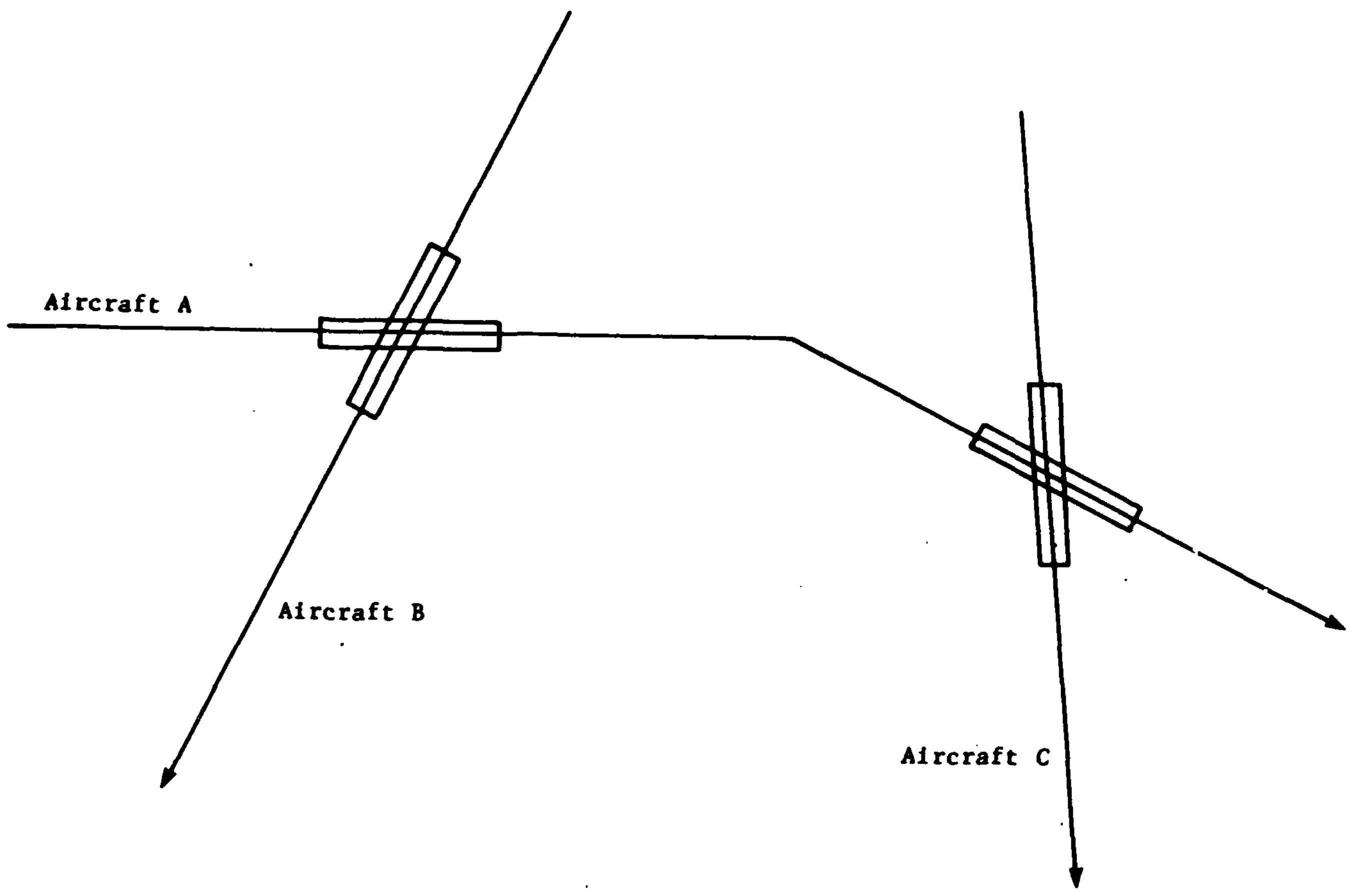

FIGURE 7-2
SAMPLE CONFLICT SITUATION PRESENTED
TO AERA 2.03 PLANNER

the second conflict will also be eliminated entirely. Thus, one maneuver has been used to avoid two possible conflicts. This is a savings not only to the pilots, but also to the controller, who now is relieved of the workload associated with resolution of that second conflict.

This example is an extremely simple one; more complex situations, especially those involving metered aircraft, might not have such a clear solution. However, it does illustrate the basic concept of the enhanced AERA 2.03 Conflict Resolution Planning function.

In the process of determining the "best" resolution, the planner will record the reasons for the particular solution which was selected. When presented with the suggested resolution advisory, the controller may request to see the justification for the system-generated resolution. By having access to this information, the controller may better evaluate alternatives.

7.2.3.1.1 Execution Stimuli

The planning functions, Conflict Resolution Planning and Metering Planning, are both initiated by the same stimuli as in previous steps.

7.2.3.1.2 Interfaces

The major difference in the interfaces for this step is the interaction between Conflict Resolution Planning and Metering Planning. The Conflict Resolution Planning function may require the services of Metering Planning, or at least be aware of the metering goals for any given aircraft.

As far as external interfaces are concerned, the output of the resolution function may now be augmented with justification of the generated resolution, upon controller request.

7.2.3.2 Deviation Resolution Planning

The Deviation Resolution Planning function is introduced in AERA 2.03 to generate resolution advisories that will direct deviating aircraft back into conformance with their cleared plans, or generate new cleared plans. Resolutions will be formulated for deviations in altitude, for lateral deviations, and possibly for speed deviations.

When a deviation is detected by the Conformance Monitoring function, a request is sent to Deviation Resolution Planning to generate a candidate planned action to restore the aircraft to its cleared plan. Trajectory Estimation is called to create a trial plan incorporating this new planned action, and the resulting plan is passed to the probes of the Problems Prediction component.

If the candidate planned action generates new conflicts, the parameters of the planned action are modified or it is exchanged for another planned action, and the modeling/probing process is repeated. When a successful plan results, the new planned action is displayed to the controller as a suggestion for returning the deviating aircraft to its cleared plan. If the controller indicates acceptance of the new planned action, the trial plan is made current.

7.2.3.2.1 Execution Stimuli

The Deviation Resolution Planning function is initiated by a request from Conformance Monitoring for a resolution to a detected deviation from the trajectory.

7.2.3.2.2 Interfaces

The external interfaces involve presentation to the controller of the suggested resolution. The internal interfaces include the request for the resolution from Conformance Monitoring, the request for modeling and probing of the trial plan, and the subsequent return of the results of the probes.

7.2.4 Plan Implementation

The functions in this area are enhanced to request or generate resolutions to detected deviations. Conformance Monitoring detects deviations from the trajectory; Tactical Execution detects deviations from the goal of a maneuver.

7.2.4.1 Conformance Monitoring

In AERA 2.03, when the Conformance Monitoring function detects a lateral or horizontal deviation, in addition to reporting the deviation to the controller, the function passes the information to the Deviation Resolution Planning function so that a resolution advisory can be presented to the controller. The processing within Conformance Monitoring does not change in this step, only the interfaces change.

7.2.4.1.1 Execution Stimuli

The stimulus for initiating the Conformance Monitoring function is not changed in AERA 2.03.

7.2.4.1.2 Interfaces

There is no change in the external interfaces. A new internal interface is the request from Conformance Monitoring to Deviation Resolution Planning to generate a resolution for a detected deviation.

7.2.4.2 Tactical Execution

When a deviation from the intent of a Planned Action is detected, the Tactical Execution function generates a resolution advisory which will put the aircraft back in conformance with the planned action.

A rather simple example of a deviation from a non-goal-oriented planned action would be the case of an aircraft which was given a clearance to reduce speed from 490 kts to 400 kts. The aircraft reduces to 440 kts and then maintains 440. Tactical Execution, which is monitoring the aircraft, detects the fact that the aircraft has stopped reducing speed and generates an advisory which would accomplish the intent of the planned action. (In this case, that may be as simple as reiterating the original clearance "Reduce to 400 kts.")

The development of clearances which compensate for deviations from a goal-oriented planned action is not so straightforward. For example, the Tactical Execution component detects that an aircraft executing a Metered Descent Planned Action is not using the expected gradient, and in fact, will not now be able to meet the metering goal. It may then generate a clearance (or clearances) to accomplish the intent of the original planned action (perhaps a new gradient for the descent). The clearance is displayed to the controller for evaluation, along with the identification of the deviation.

7.2.4.2.1 Execution Stimuli

The addition of resolution capability does not change this component's initial activation stimuli.

7.2.4.2.2 Interfaces

The change to the external interfaces involves the display to the controller of the resolution advisory, along with the identification of the deviation. The internal interfaces may also change in that Tactical Execution may wish to use the services of the Trajectory Estimation and Problems Prediction components in generating and evaluating candidate resolutions.

7.2.5 Tactical Problem Detection

There are no changes to the Tactical Problem Detection functions in AERA 2.03. The execution stimuli and interfaces remain the same as in the previous stage.

7.2.6 Tactical Problem Resolution

In AERA 2.03, the resolution advisories generated [illegible] this component are coordinated with the aircraft's trajectory in order to generate advisories which complement the immediate intent of the aircraft. In other words, an aircraft about to begin its descent to an airport would not be given an advisory to climb to avoid a conflict. (This enhancement may just as well be included in AERA 2.02 or earlier.)

7.2.6.1 Execution Stimuli

The execution stimulus for the component remains unchanged: It is activated each time the Tactical Problem Detection functions detect a tactical control problem.

7.2.6.2 Interfaces

The major difference in the interfaces is the internal use of AERA trajectories in the formulation of resolution advisories. The external interface with the controller remains unchanged.

7.3 Operational Description

7.3.1 Resolution Advisories

7.3.1.1 Stimulus

As in earlier packages, a resolution advisory is generated in response to a conflict detected by one of the automated probes (Flight Plan Conflict Probe or Airspace Probe).

7.3.1.2 Information Displayed

Resolution advisories in AERA 2.03 contain all the specifics of the resolution strategy needed for transmission of the clearance(s) to the aircraft. The level of detail is identical with that of resolution advisories presented in AERA 2.02.

7.3.1.3 Controller's Response

The expected response from the controller on receipt of an advisory is to approve the resolution as presented since it has been carefully examined by the automation and determined to be an optimal solution to the conflict. To approve an advisory, the controller would be required to make a minimum of entries into the computer, perhaps one to identify and approve/disapprove the advisory and one to verify approval.

If the controller is curious as to why a particular strategy was adopted, the rationale used by the automation function may be displayed by selecting an option on the interactive display. A textual explanation of the reasoning behind the selection would be presented on the interactive display.

The proposed resolution may be modified or replaced by the controller, in which case a comparative analysis on the computer's choice and the controller's selection can be performed to help identify where the plans differ. The results of the analysis, which could include such information as additional fuel burn and effect on metering plans, could be displayed on the interactive display.

7.3.2 Deviation Resolution Advisories

7.3.2.1 Stimulus

A deviation resolution advisory is generated when a deviation is detected by the Conformance Monitoring function. The advisory is displayed along with the deviation alert.

7.3.2.2 Information Displayed

A deviation resolution advisory contains instructions to be given to an aircraft to allow it to be reestablished on its trajectory. These instructions may or may not constitute a new clearance for the aircraft. For example, if an aircraft has drifted off to the right of its route, the advisory may advise that the aircraft "Turn left to rejoin route." This type of instruction would simply be communicated to the pilot without a

modification to the flight plan. An aircraft that was cutting a corner on its route, however, may cause the controller to instruct the pilot to fly direct to the next fix rather than turning to rejoin the cleared route. In this case, controller acceptance of the advisory would cause the flight plan to be modified and the trajectory updated.

7.3.2.3 Controller's Response

It is anticipated that the controller will implement the advisory exactly as it is presented since it contains an effective maneuver for either rejoining the trajectory or altering the trajectory and clearance to meet stated or new objectives. To implement the advisory, a single entry on the interactive display may be required from the controller. The trajectory and flight plan will be updated as appropriate.

Alternatively, the controller can implement his own plans for handling the deviation by simply instructing the aircraft to return to its route, or by issuing a new clearance to help reestablish the aircraft on its route. If a new clearance is issued, the trajectory must be updated appropriately.

7.3.3 Datalink Clearances

7.3.3.1 Stimulus

At the appropriate time for a planned clearance to be issued to the aircraft, as determined by planned actions placed on an aircraft's trajectory, a message is displayed to the controller informing the controller of the intended control action. After a specified (system parameter) amount of time, during which the controller has an opportunity to veto the clearance, the clearance is datalinked to the aircraft.

7.3.3.2 Information Displayed

The informatory message sent to the controller is identical to the Controller Reminder message sent in AERA 2.02. Only the controller's response differs. The message contains the details of the planned clearance, such as the aircraft ID, the complete clearance, and the reason for the clearance (metering, conflict resolution, etc.) to enable the controller to evaluate the planned action.

7.3.3.3 Controller's Response

The controller's response to the message depends on the action to be taken with respect to the clearance.

If the controller wants the clearance to be implemented as planned, no overt response is required. This is interpreted by the automation system as tacit approval, and the clearance will be datalinked to the aircraft at the appropriate time, which will be a system parameter amount of time after the message was presented.

If the controller wants the clearance implemented immediately, an "expedite" option is available on the interactive display which causes the clearance to be datalinked without delay.

In certain circumstances, the controller may want to postpone implementation of a clearance. To effect this a "Hold" option may be selected, which causes the clearance to be held and not datalinked. The planned action, however, remains in the trajectory and if the clearance is delayed long enough that the aircraft deviates from the expected route of flight (i.e., the trajectory), deviation alerts will be sent to the controller. To avoid this, the controller should amend the flight plan if the clearance is to be delayed a significant amount of time. A clearance placed in "hold" mode may be recalled and implemented at a later point in time.

Should the controller decide not to implement a planned clearance, the clearance may be vetoed. The planned action will be removed from the trajectory immediately.

8. AERA 3

Full automation is achieved in AERA 3, which is the end product of the automation process. The following sections give a description of the planning and control process under AERA 3. A more complete description of the ATC system under AERA 3 is available in the "AERA 3 Functional Design and Performance Description [12]."

These sections describe an automation system in which the controller becomes an optional member of the control loop and is freed to concentrate on monitoring and other activities. It is impossible at this time to specify the exact form that such a system will take. The optimum degree of automation, the best division of responsibility between the human and the computer, will depend in part upon the design of the AERA functions and on operational experience. It is quite possible that AERA 3 also will consist of a series of steps, introducing full automation to one function or area at a time. This section presents a fully-evolved AERA system.

8.1 Enhancement Features

AERA 3 represents the culmination of all the automation steps in the transition packages. The automation system has progressed from detecting possible problem areas (AERA 1), to devising control plans for particular situations (AERA 2), to finally implementing the control plans also (AERA 3). With each new package, additional control functions are assigned to the automation system, relieving the controller of the routine tasks and leaving the controller to apply his knowledge and experience to decisions requiring his expertise. By AERA 3, though the controller is still responsible for the overall control plan, it is expected that routine control actions are fully automated, and the system handles most functions without controller intervention.

If a conflict situation is detected by the Problems Prediction component, a resolution is generated by the Conflict Resolution Planning function, as in previous packages. Instead of presenting the resolution for controller approval, however, the system automatically incorporates the maneuver in the trajectory and will implement the clearance at the appropriate time. The experience gained in previous packages allows the resolution function to reliably select the optimal strategy, eliminatiug the need for prior controller approval.

The controller will receive notification of the conflict and the resolution being applied so that he can monitor the situation and intervene if a change to the control plan is required. Details of the conflict situation, the specific resolution, and the reasoning behind the resolution are available to the controller to facilitate monitoring activities.

At the time the clearance is to be transmitted to the aircraft, a datalink message is sent automatically. As when the resolution was initially generated, the controller is notified of the message being sent, but approval (tacit or otherwise) is not required or solicited. Aircraft acknowledgment is handled automatically through datalink.

In the conflict resolution process, as in the other control tasks in AERA 3, the controller can monitor the activities of the automation system, intervening only if a change is required, or can attend to other matters.

No enhancements to the metering function are implemented in AERA 3. The metering advisories have been automatically incorporated in the trajectory since AERA 2.02. The only change in AERA 3 is that the clearances are automatically datalinked to the aircraft without prior, explicit controller approval.

Machine-generated resolutions for trajectory deviations are also handled automatically. The controller receives notification of the situation, the resolution, and the transmittal of the clearance, as with conflict resolutions, for monitoring purposes.

8.2 Functional Description

In AERA 3, the majority of the planning decisions are made automatically, with the controller having the option of being kept apprised of the decisions. The diagram in Figure 8-1 shows the data flows and internal interfaces between the components. While, at first glance, this diagram may not appear appreciably different from that of the previous step, there is a very important difference. The controller is still receiving information on the state of the system, but many of the planning decisions are being made internally.

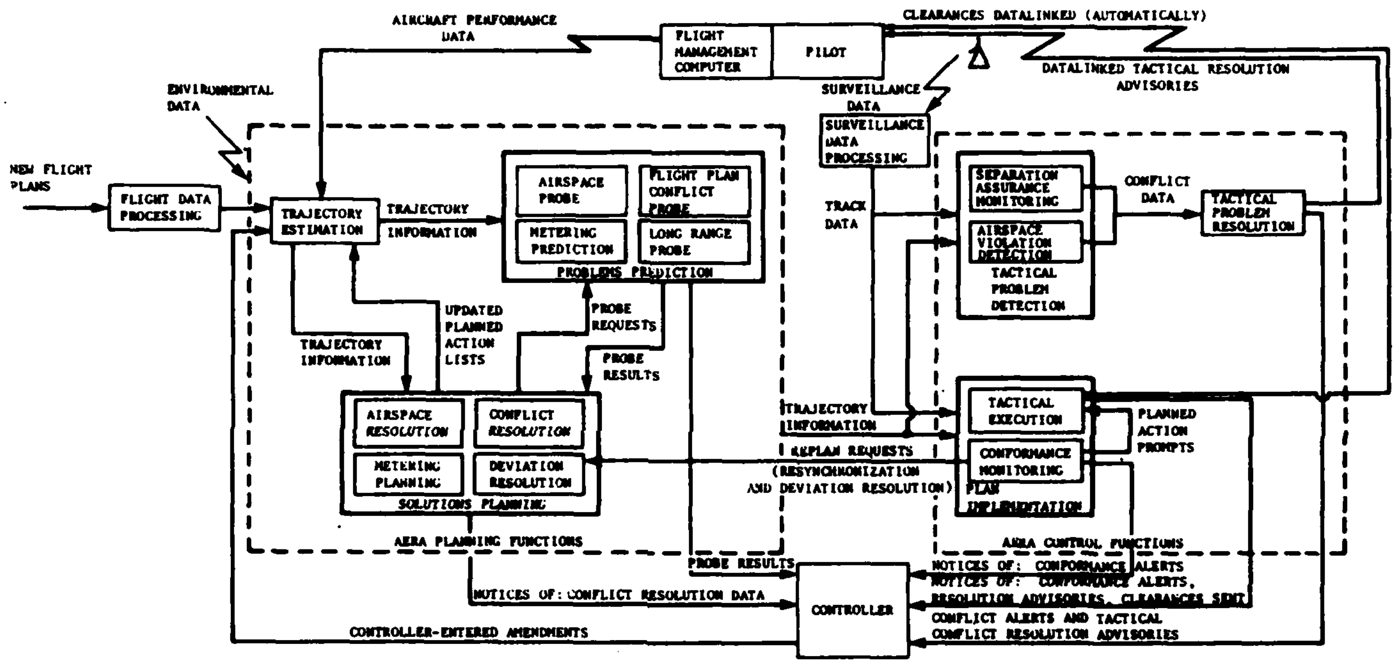

FIGURE 8-1
FUNCTIONAL COMPONENTS – AERA 3

8.2.1 Trajectory Estimation

No enhancements are added to this component for AERA 3. The execution stimuli and interfaces remain unchanged from the previous step.

8.2.2 Problems Prediction

No enhancements are added to this component--the interfaces and execution stimuli remain the same as in AERA 2.03.

8.2.3 Solutions Planning

A very significant change to this component is the absence of the controller from routine participation in the approval of advisories for resolution of strategically detected conflicts. The single resolution generated by the Conflict Resolution Planning function is incorporated into the current plan as soon as it is determined that it does, in fact, resolve the target conflict. The resolution advisory is datalinked directly to the aircraft, without relying upon the controller for approval. (When the planned action is incorporated into the current plan, it will be detected on the trajectory by the Conformance Monitoring function and sent to Tactical Execution at the proper time, to be datalinked to the aircraft.) The controller may choose to be notified of the conflict and the datalinked clearance.

The main change to this component is that the resolution advisories generated to resolve deviations from the cleared plan are not first presented to the controller for approval before being incorporated in the current plan. In AERA 3, the trial plan generated to evaluate the effect of a candidate resolution is immediately made the current plan when it is determined that it successfully "resolved" the deviation. The clearances are datalinked automatically to the aircraft, but the controller may still receive notification of any clearances sent (if he wishes), along with the notice of the deviations.

8.2.3.1 Execution Stimuli

The absence of the controller in the planning process does not affect the reasons for initiation of the Solutions Planning component--its execution stimuli are unchanged from the previous step.

8.2.3.2 Interfaces

The change in the external interfaces of this component is the removal of the interaction with the controller, required in previous steps to obtain approval of a resolution advisory. No new internal interfaces result from changes in this step.

8.2.4 Plan Implementation

There are no changes to the Conformance Monitoring function in this step. The resolution advisories generated by Tactical Execution to resolve deviations from the intent of a planned action are no longer sent to the controller for approval before being incorporated into the current plan. Following incorporation into the current plan, the resolution advisory is datalinked to the aircraft. Notice of this transaction may be displayed to the controller.

8.2.4.1 Execution Stimuli

There is no change in the execution stimuli for Tactical Execution for this step.

8.2.4.2 Interfaces

The only change in the interfaces with *Tactical Execution* is the removal of the controller interaction for approval of resolution advisories.

8.2.5 Tactical Problem Detection

No changes are introduced for this component in AERA 3. Its execution stimuli and interfaces remain the same as in the previous step.

8.2.6 Tactical Problem Resolution

By AERA 3, the Tactical Problem Resolution component has become an independent, automated conflict resolver which acts as a backup to the other AERA functions. In this step, if both types of conflict detection (trajectory-aided and projection of current velocity) are triggered simultaneously, the Tactical Problem Detection component will evaluate the two predictions and their associated resolution advisories, and determine which resolution to use. This resolution will then be sent directly to the aircraft (although, as mentioned for other components of AERA 3, the controller may choose to see the advisories).

8.2.6.1 Execution Stimuli

The conditions for initiating this component are not altered by any changes for this step.

8.2.6.2 Interfaces

For AERA 3, the Tactical Problem Resolution component may datalink Conflict Resolution Advisories directly to the aircraft (as opposed to only displaying them to the controller). This datalink capability is a new external interface--there are no new internal interfaces.

8.3 Operational Description

The controller's interactions with the automation system in AERA 3 can be grouped into two functional categories: monitoring activities and intervention in the control plan for an aircraft. The majority of the interactions will be in the first category as the controller keeps current with the traffic situation and explores the control actions planned for individual aircraft.

Since the controller no longer plays an active role in the implementation of the control plan but is still responsible for the actions taken, it is critical that the controller be able to follow the control activities performed by the automation system so that the controller can intervene if necessary and make informed control decisions. The automation system facilitates the controller's monitoring activities by displaying messages to the controller which describe problems detected, resolutions planned, and clearances implemented. These messages are for informational purposes only, not requiring any specific response from the controller. Should more detailed information on any particular aspect of the traffic picture or control plan be desired, this information is available on request.

It is not clear at this time what level of detail the controller will require to keep up to date with the control functions. The messages presented automatically to the controller should contain the majority of the information normally needed, and only on occasion should more detailed data have to be requested. The optimal format of the messages is also currently undefined. The format used may or may not be identical to the formats used in previous packages, but will be designed to optimize the process of keeping the controller aware of all control activities performed.

The second type of interaction with the automation system occurs when the controller determines, based on monitoring activities, that intervention in the planned control actions for an aircraft is necessary. Since the controller is ultimately responsible for the control plan, he may at any time change, add to, or override the machine-generated plan. The procedures for intervention are optimized for efficiency and simplicity of use, and may or may not be identical to previous procedures.

9. CONCLUSION

This report has presented a series of descriptions of the AERA packages, as currently envisioned. Both operational and functional characteristics have been discussed: what the functions are intended to do, and how they are expected to interact with the controller and other ATC f·nctions.

Each package was described in detail, in order to cover all relevant aspects to the extent possible. However, an attempt was also made to present the evolutionary context for the overall development of AREA. Each package is planned to provide a foundation for later enhancements, all leading toward the goal of full ATC automation.

This document is not intended to be a formal description of a fully developed system. There are many unresolved issues remaining, and much research and analysis to be done. This material, instead, outlines a line of development to pursue. The publication of this material is appropriate at this time, to document the current design of AERA, to provide information useful to the design of the AAS, and to stimulate discussion.

The descriptions of the individual packages will need to be expanded, as has been done already for AERA 1.01 [5], and revised as more is learned about technical and operational details. In addition, this overview of the AERA packages will need to be revised. Changes to these descriptions are not only expected, they are the desired result of documenting current thinking.

APPENDIX A

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